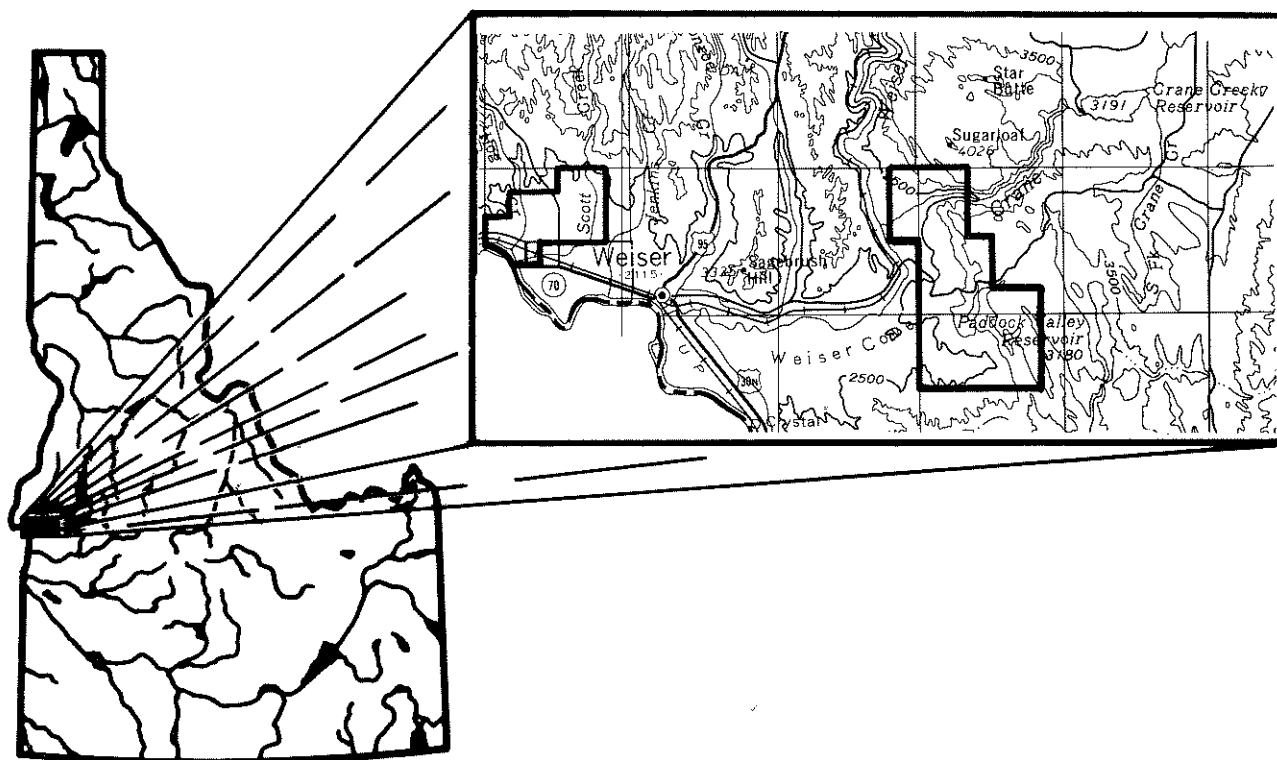


GEOHERMAL INVESTIGATIONS IN IDAHO

PART 3 AN EVALUATION OF THERMAL WATER IN THE WEISER AREA, IDAHO



IDAHO DEPARTMENT OF WATER RESOURCES

WATER INFORMATION BULLETIN NO. 30

MAY 1975

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GEOHERMAL INVESTIGATIONS IN IDAHO

Part 3

An Evaluation of Thermal Water

in the Weiser Area, Idaho

by

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Prepared by the U. S. Geological Survey

in cooperation with

the Idaho Department of Water Resources

Statehouse

Boise, Idaho

May 1975

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ABSTRACT

The Weiser area encompasses about 200 square miles in southwest Idaho and contains two thermal water areas: (1) the Crane Creek subarea, which is 12 miles east of Weiser, Idaho, and (2) the Weiser Hot Springs subarea, which is 5 miles northwest of Weiser.

Volcanic and sedimentary rocks of Miocene to Pleistocene age have been faulted and folded to form the northwest-trending anticlines present in much of the area. Basalt of the Columbia River Group or underlying rocks are believed to constitute the reservoir for the hot water.

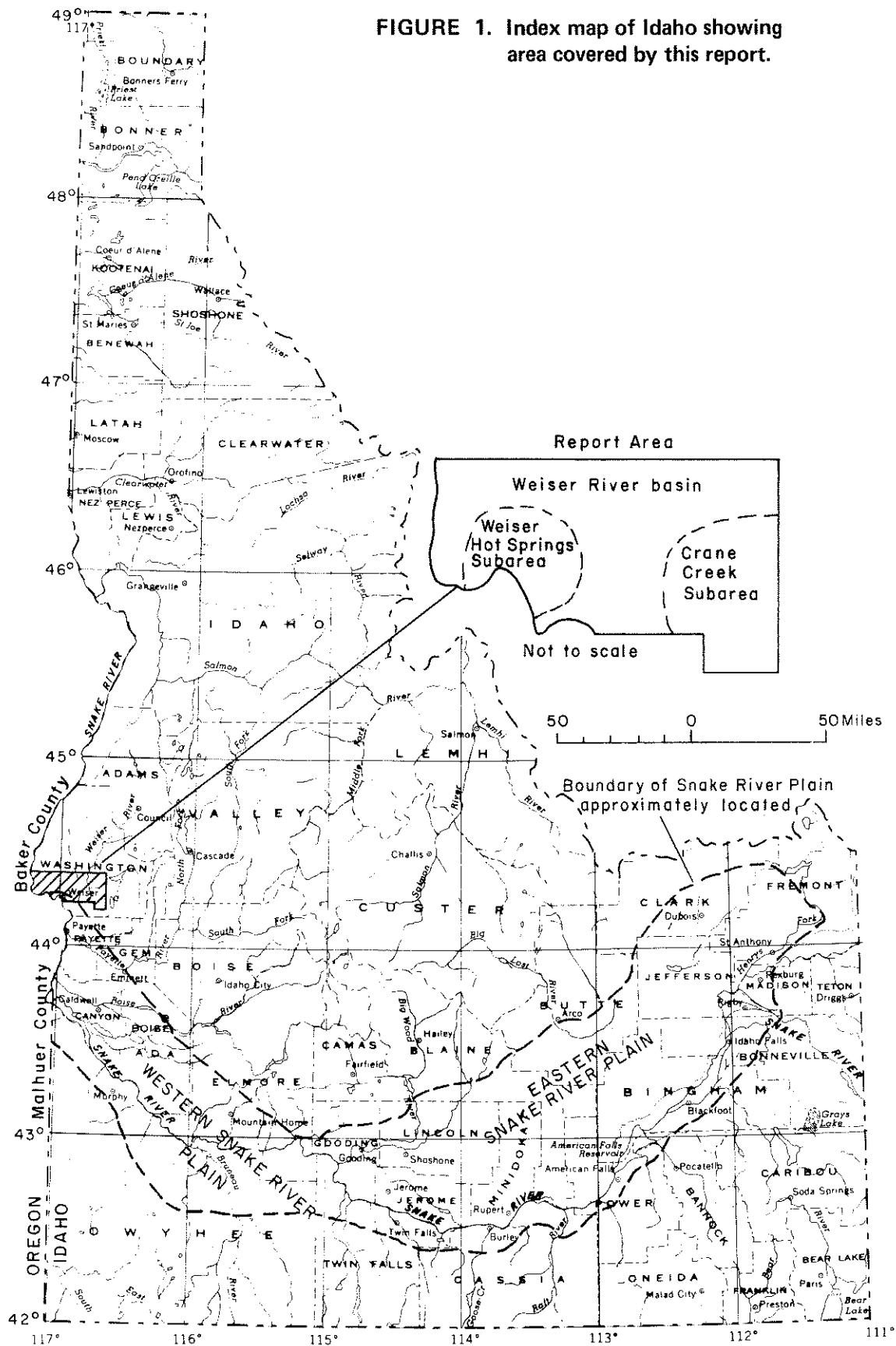
Gravity and magnetic anomalies are present in both subareas. A preliminary audio-magnetotelluric survey indicates that a shallow conductive zone is associated with each thermal site.

Above-normal ground temperatures measured at a depth of 1 metre below the land surface in the Weiser Hot Springs subarea correlate with relatively high concentrations of boron in underlying ground waters, which, in turn, are usually associated with thermal waters in the study area.

Sampled thermal waters are of a sodium chloride sulfate or sodium sulfate type, having dissolved-solids concentrations that range from 225 to 1,140 milligrams per litre. Temperatures of sampled waters ranged from 13° to 92°C. Minimum aquifer temperatures calculated from chemical analysis of water, using geochemical thermometers, were 170° and 150°C in the Crane Creek and Weiser Hot Springs subareas, respectively. Estimated maximum temperatures ranged from 212° to 270°C and 200° to 242°C, respectively, in these subareas.

The probable heat sources for both subareas are (1) young magmatic intrusive rocks underlying the basalt or (2) above-normal temperatures resulting from thinning of the earth's crust.

FIGURE 1. Index map of Idaho showing area covered by this report.



INTRODUCTION

Preliminary data describing the occurrence of hot water in the vicinity of Weiser, Idaho, were collected by Young and Mitchell (1973) as a part of their survey of thermal springs and wells in Idaho. Evaluation of these data indicated that this area might contain significant quantities of hot water and that further study of the area might reveal a potential for the development of geothermal power.

The Weiser area, as shown in figure 1, comprises about 200 square miles in southwestern Washington County and is at the northwestern end of the Snake River Plain. The area has a cool, semiarid climate with about 11 inches of precipitation annually (Ross, 1956, p. 83). The Weiser River, its tributaries, and a few small streams that flow directly into the Snake River at the western edge of the area, provide drainage for the area.

A series of northwest-trending anticlines composed of faulted volcanic and sedimentary rocks of Miocene to Pleistocene age are exposed in the northern part of the area. Lacustrine and fluvial deposits of Pliocene to Holocene age underlie the lowlands in the southern part of the area. Altitudes in the area range from about 2,000 feet in the lowland to about 4,000 feet on the higher ridges.

The two known major occurrences of hot water in the Weiser area are widely separated; for this reason, in this report, the area has been divided into two subareas to facilitate discussion of the thermal anomaly each contains. The subareas are: (1) Crane Creek, which is about 12 miles east of Weiser; and (2) Weiser Hot Springs, which is located about 5 miles northwest of Weiser (fig. 1). The name Weiser Warm Springs is given on the Olds Ferry and Olds Ferry SE U.S. Geological Survey topographic quadrangle maps, but in this report, these springs are referred to by the local name of Weiser Hot Springs.

The Crane Creek subarea contains two groups of undeveloped hot springs that lie along the banks and in the stream channels of Crane Creek in T. 11 N., R. 3 W., sec. 7, and of Cove Creek in T. 10 N., R. 3 W., sec. 9 (for locations, see figs. 4 and 6). The water from these springs is unused and discharges into the streams. The hot springs along Crane Creek are at the mouth of a steep-walled canyon that is cut in sandstone and volcanic rocks of Miocene and Pliocene age. The Cove Creek site is in a relatively shallow draw cut in fine-grained sedimentary deposits, with the springs issuing from the coarser alluvium in the stream channel.

In the Weiser Hot Springs subarea, thermal water is obtained from wells drilled near the original hot springs. These springs no longer flow noticeably at the surface, although several

nearby wells and springs discharge small amounts of warm water. Thermal water produced from four closely spaced wells at the Weiser Hot Springs is used to fill a swimming pool and to heat two greenhouses. Water from other nearby wells and warm springs is used to water livestock and to irrigate small pasture areas.

Purpose and Scope

After Young and Mitchell (1973) recognized that the Weiser area could have significant potential as a source of geothermal energy, the U.S. Geological Survey, in cooperation with the Idaho Department of Water Resources, initiated a study whose purpose was to better define the geothermal resources in the area. This purpose is met in this report by presenting (1) chemical analyses of water from selected wells and springs for use in estimating aquifer temperatures at depth and in describing the chemical character of the thermal waters; (2) a geologic map of the area prepared from existing data; (3) an outline of areas of anomalous ground temperatures measured at a depth of 1 metre; and (4) results of geophysical surveys made as an aid to understanding the structure of the underlying rocks and to help in locating geophysical anomalies in the subsurface.

Water samples were collected from 11 wells and 9 springs for standard chemical analyses, which include the common ions and silica. Additional samples were collected for analyses of the less abundant elements -- mercury, lithium, boron, and arsenic. Samples were also collected from cold-water wells and springs for background data. Samples of deposits from hot springs were analyzed to determine their mineral constituents.

Data derived from previous geologic reports were used to prepare a geologic map for the area. The geologic data were modified from reports by Shah (1966), Ross (1956), and Kirkham (1931b).

Ground temperatures measured at a depth of 1 metre at 74 stations were used to prepare a map showing the extent of warmer ground in the vicinity of the Weiser Hot Springs. Additional information on the extent of the geothermal anomalies was derived from analysis of gravity and aeromagnetic data, plus some reconnaissance audio-magnetotelluric data by D. R. Mabey, D. L. Peterson, D. B. Hoover, and L. L. Tippens of the U. S. Geological Survey.

Previous Work

Reports by Russell (1902 and 1903), Dorf (1936), McDivitt (1952), Newton and Corcoran (1963), Washburne (1909), Kirkham (1927), and Anderson (1941) contain some data on the geology, paleobotany, and the potential for producing natural gas in the Weiser area. These reports are generalized and are of a reconnaissance nature. Data from more detailed reports by Shah (1966), Kirkham (1931b), and Ross (1956) were mainly used to compile a geologic map for the Weiser area (fig. 4). In figure 4, the individual units of the Idaho Group as described by Shah (1966) are not shown separately but are included in the Idaho Group, undifferentiated. Also, the locations of some anticlines, synclines, and the outcrop area of pre-Tertiary rocks shown in the geologic map (fig. 4) were taken from Kirkham (1931b). In addition, several areas of mineralization shown by Ross (1956) are included in figure 4.

Acknowledgments

The authors wish to express their gratitude to the many residents of the Weiser area who supplied information on their wells and springs and allowed access to their property.

Well- and Spring-Numbering System

The numbering system used by the Geological Survey in Idaho indicates the location of wells or springs within the official rectangular subdivision of the public lands, with reference to the Boise base line and meridian. The first two segments of the number designate the township and range. The third segment gives the section number, followed by three letters and a numeral, which indicate the quarter section, the 40-acre tract, the 10-acre tract, and the serial number of the well within the tract, respectively. Quarter sections are lettered a, b, c, and d in counterclockwise order from the northeast quarter of each section (fig. 2). Within the quarter sections, 40-acre and 10-acre tracts are lettered in the same manner. Well 11N-6W-10cca1 is in the NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 10, T. 11 N., R. 6 W., and was the first well inventoried in that tract. Springs are designated by the letter "S" following the last numeral, 11N-3W-7bdb1S.

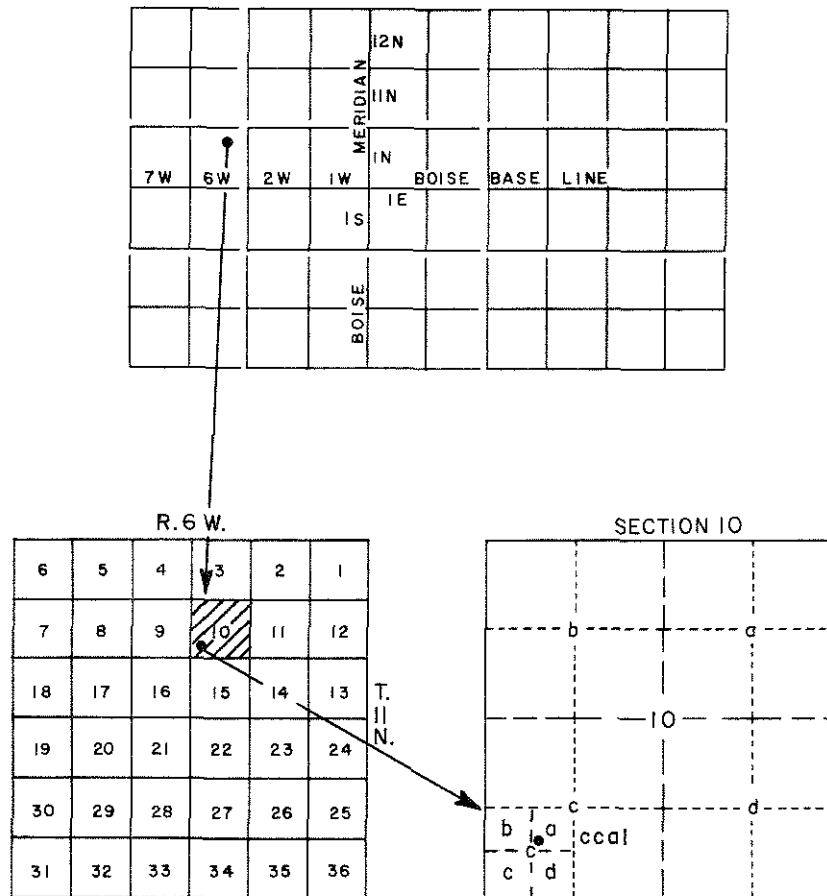


FIGURE 2. Diagram showing the well- and spring-numbering system. (Using well 11N-6W-10cca1.)

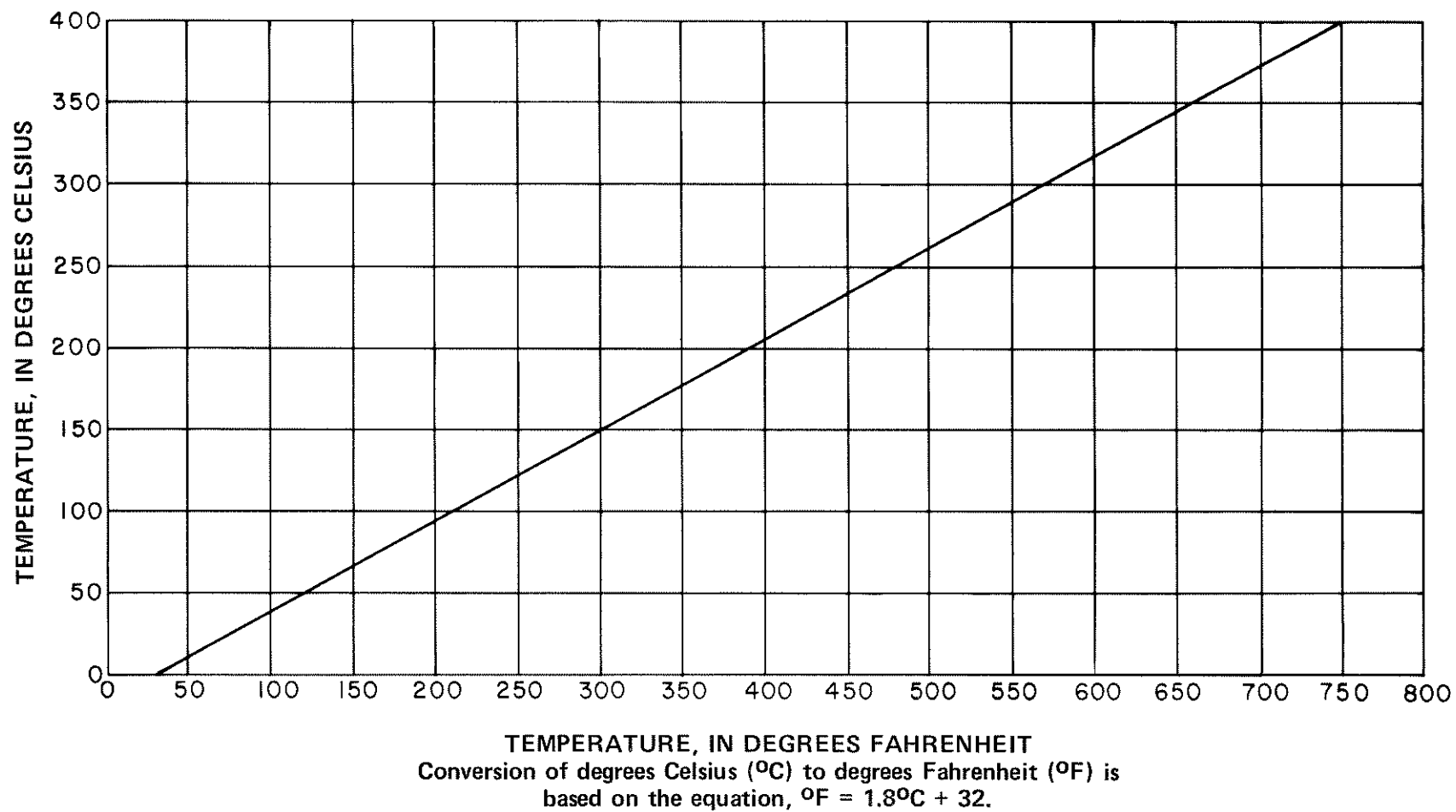


FIGURE 3. Temperature-conversion graph.

Factors for Converting English Units to International System (SI) Units

The International System of Units is being adopted for use in reports prepared by the U. S. Geological Survey. To assist readers of this report in understanding and adapting to the new system, many of the measurements reported herein are given in both units. In addition, a graph (fig. 3) and the factors listed below are presented as an aid to conversion from one system of units to another. Chemical data for concentrations are given only in milligrams per litre (mg/l) or micrograms per litre (ug/l) because these values are (within the range of values presented) numerically equal to equivalent values expressed in parts per million, or parts per billion, respectively.

Multiply English Units	By	To Obtain SI Units
<u>Length</u>		
inches (in)	25.4	millimetres (mm)
feet (ft)	.3048	metres (m)
miles (mi)	1.609	kilometres (km)
<u>Area</u>		
acres	.4047	hectares (ha)
square miles (mi ²)	2.590	square kilometres (km ²)
<u>Flow</u>		
cubic feet per second (ft ³ /s)	28.32	litres per second (l/s)
gallons per minute (gal/min)	.06309	litres per second (l/s)

TABLE 1

DESCRIPTION AND WATER-BEARING CHARACTERISTICS OF GEOLOGIC UNITS IN THE WEISER AREA, IDAHO

ERA	PERIOD	EPOCH	ROCK UNIT	DESCRIPTION	WATER-BEARING CHARACTERISTICS
Cenozoic	Quaternary	Holocene and Pleistocene	Alluvium and Colluvium (Qal)	Clay, silt, sand, and gravel; chiefly fluvial deposits. Includes some landslide materials. Thickness is variable.	Yields adequate supplies of water to domestic and stock wells. Important locally as an aquifer.
Cenozoic	Quaternary and Tertiary	Pleistocene and Pliocene	Idaho Group, undifferentiated (QTiu)	Fluvial and lake deposits of clay, silt, sand, and gravel, compacted to poorly consolidated, poorly to well stratified. Contains beds of ash and intercalated basaltic lava flows. Exceeds 1,500 feet in thickness in the Weiser River Valley near Weiser. Exceeds 4,000 feet near Ontario, Oregon about 16 miles south of Weiser (Kirkham, 1931a).	Hydraulic conductivity highly variable. Generally contains confined water, yields to wells range from a few gallons per minute to several hundred gallons per minute. Important as an aquifer.
Cenozoic	Tertiary	Pliocene and Miocene	Basalt of the Columbia River Group (Tcr)	Flood-type basalt, light- to dark-gray, dense; crude columnar jointing at places; folded and faulted; may include some andesitic and rhyolitic rock types. The Payette Formation is sandwiched between units of this basalt at places, which is a characteristic feature distinguishing the Payette Formation from sediments of the Idaho Group. Thickness of the upper basalt unit exceeds 1,000 feet in the canyon of Crane Creek just east of the study area, other measured thicknesses range from 445 to 680 feet at places in and near the study area (Kirkham, 1931a).	Unknown in Weiser area; but generally yields are highly variable in areas where wells are producing from this aquifer.
Cenozoic	Tertiary	Pliocene(?) and Miocene	Payette Formation (Tp)	Compacted beds of clay, silt, sand, and volcanic ash, intercalated in basalt of the Columbia River Group. Thickness of this unit is about 1,000 feet (Anderson, 1941).	Unknown, but possibly could be an aquifer in places.
Mesozoic and Paleozoic	Pre-Tertiary		Pre-Tertiary Rocks, undifferentiated (pT)	Permian and younger igneous rocks, includes some well indurated sedimentary rocks of the Seven Devils Volcanics that have been faulted and folded, and includes some granitic rocks of the Idaho batholith. Total thickness of the volcanics is not known, but it exceeds 10,000 feet (Kirkham, 1931b). Thickness of the granitic rocks is unknown.	Generally very low in hydraulic conductivity. Not important as an aquifer in this area.

GEOLOGY

Wells and springs discharging warm to hot water are found at several places along the northern margin of the western Snake River Plain between Weiser and Boise, a distance of about 60 miles. Evidence from gravity, seismic, and geologic studies indicates that the western part of the Snake River Plain is a graben with high-angle northwest-trending faults along its northern flank (Malde, 1959). Malde also found that along this flank of the graben, rocks of early and middle Pliocene age have been displaced at least 5,000 feet; that younger rocks have, with time, experienced progressively smaller displacements totaling about 4,000 feet; and that very little displacement has occurred in the youngest rocks of late Pleistocene age.

The lowlands in the southern part of the Weiser area are, according to Kirkham (1931c), within a part of the downwarped Snake River Plain, and some faulting associated with the downwarping has occurred along the margins of the lowlands. Data from a few well logs also indicate that a fault probably exists along the northern edge of the lowlands.

A system of northwest-trending, eroded, and, in some places, faulted anticlines composed of volcanic and sedimentary rocks occurs in the northern part of the Weiser area (fig. 4). This system of anticlines dips toward and abruptly terminates at the northern margin of the structurally depressed Snake River Plain where it cuts through the Weiser area (fig. 10). The lowlands in the southern part of the Weiser area are underlain by a thick sequence (greater than 1,500 feet) of relatively undisturbed sedimentary rocks (Kirkham, 1931a, p. 237).

The rocks in the Weiser area range in age from pre-Tertiary (Permian) to Quaternary. (See table 1 and fig. 4). Volcanic rocks of Permian and younger age and granitic rocks of Cretaceous age underlie volcanic rocks of the Columbia River Group of Miocene and Pliocene age as evidenced by exposures in the canyon of the Snake River in T. 11 N., R. 7 W., sections 5, 8, and 20 along the western edge of the study area. Although these small exposures are not shown on the geologic map, an exposure of pre-Tertiary-age rocks in the northwestern part of the area is shown.

The volcanic rocks of the Columbia River Group are believed to underlie most of the area (Shah, 1968). Basaltic volcanic rocks of the Columbia River Group occur both above and below the rocks of the Payette Formation of Miocene and Pliocene(?) age. Kirkham (1931a, p. 213) stated that known thicknesses of the basalt overlying the Payette Formation range from 445 to 1,000 feet in and near the Weiser area. The occurrence of the Payette

Formation within basalts of the Columbia River Group is a characteristic feature that helps to distinguish the Payette Formation from rocks of the Idaho Group that overlie the younger basalts of the Columbia River Group. Rocks of the Idaho Group range from Pliocene to Pleistocene age and are widespread throughout the area. In the lowlands and valleys, alluvium and colluvium of Pleistocene and Holocene age generally overlie the older rock units.

As indicated in the preceding discussion, faulting and folding of rocks has occurred along the flanks of the northern margin of the Snake River Plain, and from this, it can be inferred that deep-seated faulting may also have occurred in the Weiser area. Faulting of this nature could provide conduits for the intrusion of magma to relatively shallow depths, which, in turn, could be a source of heat for overlying ground water. These faults could also act as conduits enabling circulation of water to hot rocks at depth. Outcrops of silica-cemented sandstone and conglomerate in the Payette Formation and in the Idaho Group seem to be associated with occurrences of thermal water.

The thermal springs in the Crane Creek subarea are in the canyons of Crane Creek and Cove Creek and are aligned in a northwesterly direction, which is parallel to the structural trend of the area. The subarea is centered around the site of the Idaho Almaden Mines Company mine, which was at one time a leading producer of mercury (quicksilver) in the United States. The mine, which is about 12 miles east of Weiser and is between the two groups of hot springs in the Crane Creek subarea, is in a sag on the crest of a northwest-trending anticline (Anderson, 1941, see fig. 4). The Crane Creek hot springs and the Cove Creek hot springs are on the eastern and western limbs of this anticline. Thermal water at both sites issues from alluvium and colluvium. A sandstone, which is underlain by basalt of the Columbia River Group, is exposed on the hillsides above the spring vents and is believed to be part of the Payette Formation.

In this subarea, the Payette Formation and Idaho Group were mineralized by hydrothermal action. Much of the rock has been permeated by silica-rich (opal) hydrothermal solutions, and in some places, mercury (in the form of cinnabar) was deposited. The mineralization occurred during several pulses, the last of which, according to Anderson (1941, p. 8), could have been no older than early Pleistocene. The hydrothermal solutions probably rose along faults and may have resulted from shallow(?) magmatic intrusions associated with zones of tension fractures. The hot springs in the Crane Creek subarea may represent a modern manifestation of the same processes that produced the mineralization.

The Weiser Hot Springs subarea is at the margin of the lowlands near the crest of an anticline (fig. 4). No intensive mineralization, such as in the Crane Creek subarea, has been noted. However, in T. 11 N., R. 6 W., in the north half of section 10, an outcrop of silica-cemented and, in places, opalized sandstone is present (not shown on the geologic map), which is similar to the sandstone at the site of the Idaho Almaden Mines Company mercury mine. Several warm-water springs and wells are present near the sandstone ridge.

In the Weiser Hot Springs subarea, wells at the Weiser Hot Springs may be supplied with water from basalt of the Columbia River Group. Evidence for this is from the driller's log for well 11N-6W-10cca1, which indicates that a hard, multicolored rock unit (basalt?) was penetrated at 83 feet below land surface. Although this rock unit probably is basalt of

the Columbia River Group, wells to the south and southeast of Weiser Hot Springs have not penetrated this basalt, possibly because most of these wells are less than 200 feet deep, and because of faulting along the northern margin of the lowlands (fig. 10).

Other wells and springs in the subarea are supplied with water from surficial deposits of alluvium and from sedimentary rocks of the Idaho Group that overlie basalt of the Columbia River Group. The areal alignment (fig. 4) of springs 11N-6W-10acb1S and 11N-6W-18ccc1S, well 11N-6W-17bdd1, and the hot wells at Weiser Hot Springs, in addition to the similarity of ratios of selected chemical constituents in water from these wells and springs (see section on chemical ratios), suggest that the water probably rises along a fault to issue at the surface or enter shallow aquifers.

Based on meager data from drillers' logs and the known geology of the Weiser area, the reservoir rocks for the thermal water in the Crane Creek and Weiser Hot Springs subareas are probably the basalts of the Columbia River Group or underlying rocks of Cretaceous to Permian age.

GEOPHYSICAL SURVEYS

Regional Gravity and Magnetic Anomalies

A gravity map (fig. 5) of the Weiser area was compiled by D. R. Mabey and D. L. Peterson of the U.S. Geological Survey using 59 stations established by the Survey and 32 stations obtained from the Department of Defense Gravity Library. The Bouguer-anomaly gravity values were computed using a density factor of 2.67 g/cm^3 (grams per cubic centimetre). No correction for terrain effect has been applied. The data are referenced to the North American gravity base station at the Boise airport at the south edge of Boise (Woollard, 1958). The station density is low, and the gravity map defines only the gross character of the more extensive gravity anomalies.

The Weiser area lies at the northwest end of a large regional gravity high that is approximately coextensive with the entire length of the Snake River Plain. Elsewhere, most of the area encompassing this large gravity high is underlain by sedimentary and volcanic rocks of Tertiary and Quaternary age. In the Weiser area, however, the high extends over an area underlain by basalt of the Columbia River Group. This basalt may be part of the cause of the gravity high, but a positive mass anomaly at depth related to isostatic compensation for the low average surface altitude relative to areas to the west, north, and east is also a probable cause of part of the anomaly. Over the western Snake River Plain, this deeper mass anomaly appears to reflect a pronounced thinning of the upper crust.

The highest Bouguer gravity values in the Weiser area occur west of Weiser where the average surface altitude is the lowest in southern Idaho. Bouguer gravity values decrease north and east toward areas of higher average surface altitudes. Data presently available do not define the gravity high west of Weiser in adequate detail to determine if the related positive mass is in the near surface or buried deep in the crust.

East of the Weiser River in the area of Crane Creek is an extensive gravity low. On the west, the low is bounded by a steep gravity gradient that suggests a high-angle interface between rock units of different density. One possible interpretation of the anomaly is a thickening of low-density sediments in the area of the gravity low.

In the area of Weiser Hot Springs, northwest of Weiser, a low-amplitude gravity high is apparently related to a near-surface-mass anomaly; however, no indication of the cause of the anomaly has been reported.

Aeromagnetic data are available from a survey flown 11,000 feet above mean sea level with north-south flight lines 2 miles apart (fig. 6). The magnetic intensity in the Weiser area is generally high, presumably reflecting the abundance of strongly magnetic basalt.

West of Weiser, the north end of a magnetic low extends into the area of the Weiser Hot Springs. This anomaly can be produced by structure affecting the basalt, by variations in magnetic properties of the basalt, or by a greater abundance of sedimentary rocks in the subsurface.

A north-northwest-trending magnetic high separates a magnetic low west of Weiser from another low to the east. The eastern low appears to be related to the gravity low in this area and could also be produced by a thickening of low-density sediments.

Audio-Magnetotelluric Surveys

A preliminary AMT (audio-magnetotelluric) survey was conducted by D. B. Hoover and C. L. Tippens of the U.S. Geological Survey in both the Crane Creek and Weiser Hot Springs subareas. The survey consisted of two soundings in the Crane Creek subarea and three soundings in the area of the Weiser Hot Springs. A complete description of the AMT method is given in "Geothermal Investigations in Idaho, Part 2, An evaluation of the thermal water in the Bruneau-Grand View area, southwest Idaho" by Young and Whitehead (1974).

The soundings (written comm., D. B. Hoover, 1974) in the Crane Creek subarea indicate apparent resistivities of 10 to 20 ohm-metres at the surface and at an intermediate level with an apparent resistivity of 1 ohm-metre at depth. The soundings in the Weiser Hot Springs subarea were generally under 10 ohm-metres with a gradual decrease in apparent resistivity with depth.

Although the number of AMT soundings in the Crane Creek and Weiser Hot Springs subareas are too few to indicate the areal extent of any possible existent geothermal system, they do indicate that a resistivity anomaly of unknown size does exist at depth.

Ground-Temperature Survey in the Weiser Hot Springs Subarea

The occurrence of anomalous ground temperatures in the area surrounding a hot spring has been used to delineate the size and shape of a thermal anomaly. Ground temperatures at 1-metre depth (39.37 inches) were used to indicate the boundaries of an area of high heat flow at Wairakei, New Zealand, by Thompson (1960).

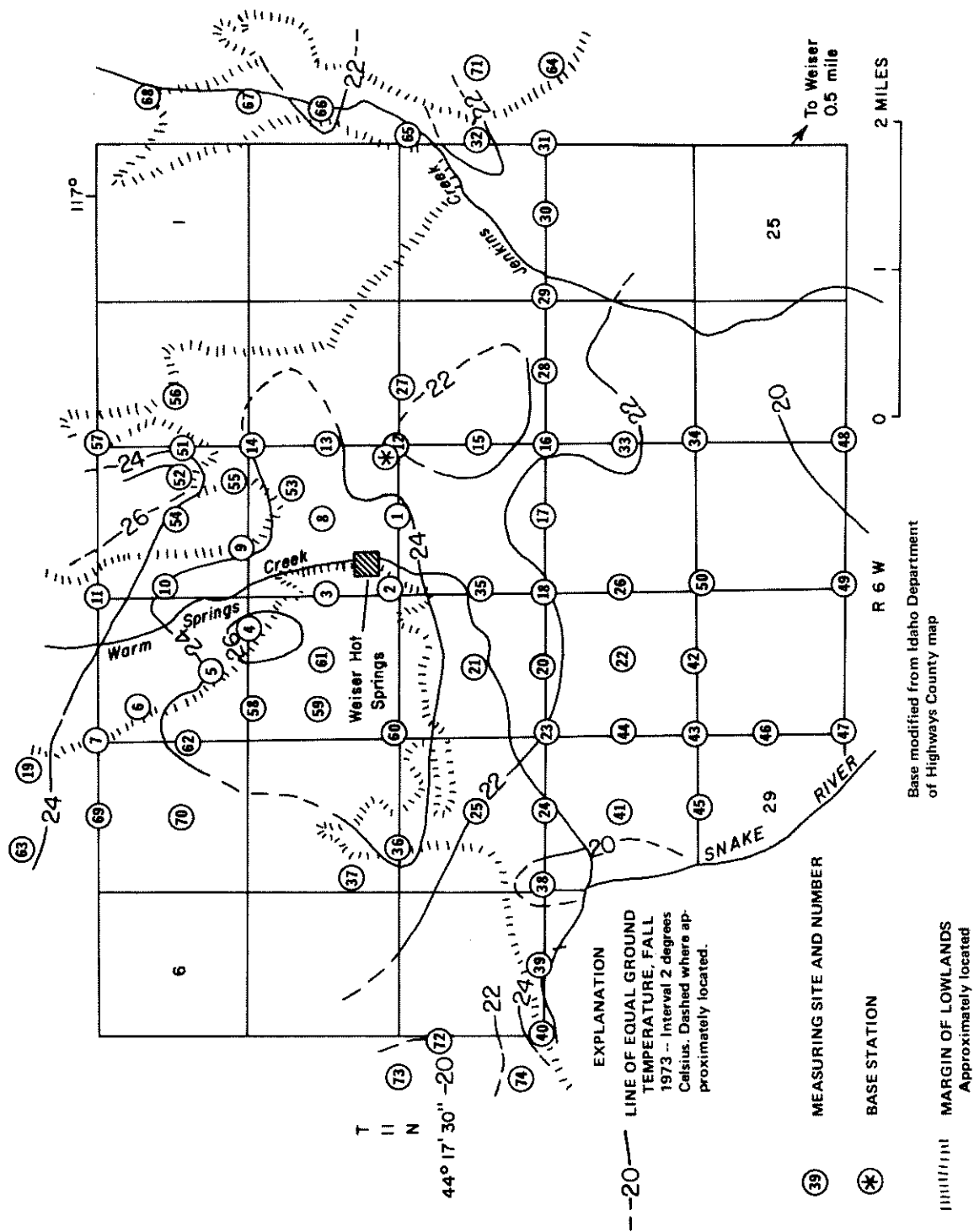
Ground temperatures were measured at a depth of 1 metre at 74 sites (spaced on a one-half mile grid) in the vicinity of the Weiser Hot Springs during the period August 30 to September 19, 1974. Seasonal and diurnal temperature changes occurring during the survey were corrected using ground temperatures that were monitored continuously at a site located in the southeast corner of section 10, T. 11 N., R. 6 W., approximately 0.75 mile east of Weiser Hot Springs.

The procedure used to measure ground temperatures at the selected sites is as follows:

1. A hole was driven into the ground to a depth of 1 metre, and a temperature probe was inserted.
2. Five minutes after inserting the probe, a series of five ground-temperature readings were recorded at 2-minute intervals, and an equilibrium temperature was calculated using a method by Parasnis (1971).
3. Ground temperatures were then obtained by adjusting the calculated equilibrium temperatures for the seasonal and diurnal fluctuations observed at the monitor site during the survey.

The results of the ground-temperature survey for the Weiser Hot Springs subarea are shown on figure 7 by lines of equal ground temperatures. In addition, the extrapolated and the adjusted temperature for each measuring site and the recorded seasonal variation (August 1973 to March 1974) for the area are also shown on figure 7. As shown by figure 7, ground temperatures in the immediate vicinity of Weiser Hot Springs are 2° to 6°C higher than in the surrounding area, and the area of higher ground temperatures encompasses the area of hot springs and wells.

Chemical analyses of ground-water samples collected within or near the 24°C line (fig. 7) around the Weiser Hot Springs show that higher boron concentrations (table 2) occur here than elsewhere in the area. The correlation between ground temperatures and boron concentrations indicates the possibility that the high boron concentrations found may be indicative of thermal water leaking upward from depth.



Site No.	Extrapolated Temperature	Adjusted Temperature	Site No.	Extrapolated Temperature	Adjusted Temperature
1	25.0	24.2	36	24.2	24.2
2	25.6	24.8	37	23.6	23.6
3	25.1	24.3	38	19.1	19.1
4	27.4	26.6	39	24.9	24.9
5	24.8	24.0	40	25.7	25.7
6	20.7(?)	19.9	41	20.1	20.1
7	24.3	23.5	42	22.3	22.3
8	24.9	24.1	43	21.8	21.9
9	24.7	23.9	44	21.4	21.5
10	24.8	24.0	45	21.1	21.2
11	26.0	25.2	46	21.4	22.2
12	22.9	22.0	47	19.7	20.5
13	25.1	24.3	48	19.5	19.6
14	25.0	24.2	49	20.3	20.4
15	22.6	21.8	50	21.8	21.9
16	23.1	22.3	51	22.8	22.9
17	21.6	20.8	52	26.6	26.7
18	23.5	22.7	53	24.3	24.4
19	25.8	25.0	54	23.6	23.7
20	25.5(?)	25.1	55	23.0	23.1
21	23.1	22.7	56	21.4	21.5
22	17.3(mud on probe)	16.9	57	23.0	23.1
23	22.4(?) (probe wet)	22.0	58	24.9	24.3
24	21.4	21.0	59	24.5	24.5
25	22.4	22.0	60	24.5	24.6
26	20.4	20.1	61	21.0(?)	20.9
27	22.7	22.4	62	24.5	24.4
28	22.4	22.1	63	25.8	25.5
29	22.8	22.6	64	23.3	22.1
30	23.9	23.6	65	24.1	22.9
31	24.4	24.1	66	22.7	21.5
32	21.8	21.5	67	24.7	23.5
33	22.8	22.6	68	24.0	22.8
34	20.9	20.7	69	24.6	23.4
35	22.9	22.7	70	20.1(?)	19.0
			71	23.8	23.4
			72	20.8	20.4
			73	19.6	19.2
			74	23.6	23.2

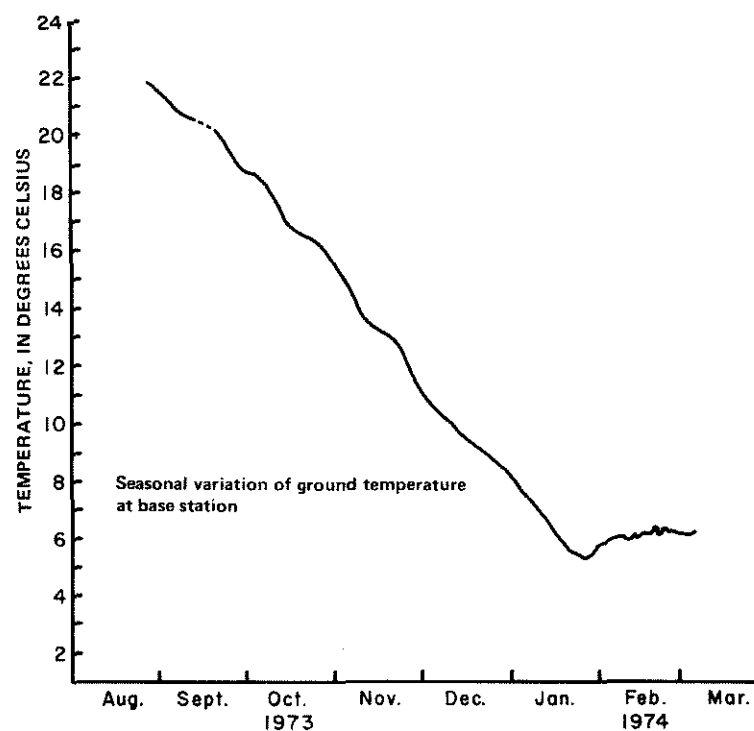


FIGURE 7. Lines of equal ground temperatures, extrapolated and adjusted ground temperature at measuring sites, and the seasonal variation of ground temperature at 1-metre depth in the Weiser Hot Springs subarea, Idaho.

TABLE 2

CHEMICAL ANALYSES OF WATER FROM SELECTED WELLS AND SPRINGS IN THE WEISER AREA, IDAHO

(Chemical constituents in milligrams per litre except where noted)

Well or Spring Identification Number	Reported Well Depth below Land Surface (feet)	Date of Collection	Discharge (cubic feet per second)	Silica (SiO ₂)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO ₃)	Carbonate (CO ₃)	Alkalinity as CaCO ₃	Sulfate (SO ₄)	Chloride (Cl)	Fluoride (F)	Nitrite plus Nitrate (NO ₂ + NO ₃)	Phosphorus (P)	Dissolved Solids (calculated)	Dissolved Solids (tons per acre-ft)	Hardness		Percent Sodium Adsorption Ratio	Specific Conductance (field)	pH (field)	Water Temperature (°C)	Chemical Constituents in Micrograms Per Litre				
																			as CaCO ₃	Noncarbonate					Arsenic (As)	Boron (B)	Lithium (Li)	Mercury (Hg)	
12N-7W-24add1S		8-6-73	0.01	47	20	3.6	24	7.5	129	0	106	22	3.3	0.4	0.04	0.02	192	0.26	65	0	41	1.3	273	7.9	15.0	18	0	40	0
12N-4W-34ab1S		8-7-73	.01	54	30	11	13	3.9	167	0	137	13	3.5	.7	1.0	.19	216	.29	120	0	18	.5	264	7.4	13.5	41	0	20	0
11N-6W-34b1	600	8-8-73	.01	42	4.4	0	120	.6	67	0	55	180	28	1.9	.01	.03	412	.56	11	0	96	16	624	8.6	23.5	8	2,000	10	0
34ab1	218	8-7-73	.01	77	4.0	.1	130	1.2	15	36	72	150	55	.6	0	0	464	.63	10	0	96	18	579	7.4	25.0	0	2,400	20	0
94b1	246	8-8-73	-	20	1.7	.1	130	1.0	214	0	176	21	56	5.0	.01	.20	342	.47	5	0	98	26	562	8.3	14.5	17	1,400	50	.1
10ac1S		8-6-73	.01	31	12	1.8	50	1.4	44	0	36	53	17	1.2	8.0	.08	225	.31	37	1	74	3.6	335	7.3	21.5	5	820	0	0
10ca1	400	8-2-72	.01	140	2.9	0	140	5.0	35	38	92	150	56	3.3	1.0	.06	573	.78	7	0	96	23	726	9.3	70.5	0	2,200	40	0
10ca2	102	8-23-73	-	130	2.7	.1	140	5.3	33	41	95	150	52	3.9	.01	.18	544	.74	7	0	96	23	683	9.1	77.0	5	2,200	50	0
10ca3	91	8-2-73	-	140	2.6	0	140	4.8	32	37	88	150	56	2.9	.03	.01	566	.77	6	0	96	25	734	9.2	76.0	4	2,100	50	0
15bc1S		8-8-73	.04	83	25	8.5	130	6.6	171	0	140	180	45	1.8	1.0	.24	570	.78	97	0	73	5.7	793	6.6	14.5	10	1,400	50	0
17bd1		9-7-73	.01	26	19	0	91	.6	3	21	37	130	53	1.4	5.2	.09	369	.50	47	10	80	5.8	534	9.2	18.5	21	2,100	50	.1
18cc1S		9-7-73	.01	21	19	.7	250	.2	18	0	15	510	36	2.6	.01	.10	852	1.16	50	36	92	15	1,240	7.7	17.0	0	4,100	140	0
25ca1	39	10-10-73	-	52	66	29	48	3.7	392	0	322	41	4.6	.4	6.2	.29	466	.63	280	0	27	1.2	648	7.3	13.0	19	120	10	0
11N-5W-20bd1	195	8-9-73	-	54	31	5.3	21	6.9	136	0	112	25	6.8	.5	1.8	.10	226	.31	99	0	30	.9	271	7.2	21.0	14	50	50	0
11N-4W-12cb1	90	8-27-73	-	25	13	2.3	89	8.7	232	0	190	13	17	.1	2.3	.99	294	.40	42	0	79	6.0	447	8.3	15.5	170	590	130	.2
12cd1	30	8-27-73	-	48	20	8.2	13	8.4	119	0	98	8.4	2.1	.2	3.1	.41	181	.25	84	0	23	.6	203	7.0	17.0	3	110	10	.2
11N-3W-7bd1S		8-2-73	.01	180	29	.5	280	18	201	0	165	250	200	3.2	.01	.19	1,070	1.46	74	0	86	14	1,630	7.8	92.0	41	10,000	620	.3
7bdb2S		8-2-73	.01	190	29	.6	280	19	202	0	166	250	200	3.2	.04	.03	1,080	1.47	75	0	86	14	1,570	8.0	57.0	44	10,000	630	.1
7cbb1S		10-1-73	.10	180	26	.3	290	18	197	0	162	240	200	3.8	1.4	.03	1,070	1.46	66	0	88	16	1,500	7.1	77.0	42	11,000	660	0
10N-3W-9cc1S		8-9-73	.01	130	20	.2	320	22	107	0	88	270	310	4.7	0	.12	1,140	1.55	51	0	90	20	1,940	7.4	74.0	510	7,800	560	.3

Analyses by: U. S. Geological Survey

GEOCHEMICAL SURVEYS

Eleven wells and nine springs in the Crane Creek and Weiser Hot Springs subareas (fig. 4) were selected for water-quality sampling on the basis of measured water temperature and their proximity to the two thermal anomalies under investigation. Water samples collected from these wells and springs are believed to be representative of the thermal and nonthermal ground waters in each subarea. A standard chemical analysis, plus mercury, boron, arsenic, and lithium for each well or spring sampled is given in table 2. In the following pages, these analyses are used to provide a chemical characterization of the water sampled, to estimate aquifer temperatures at depth, and to calculate the ratios of selected chemical constituents.

Samples of hot-spring deposits from four active spring vents and three inactive spring vents were also collected for mineral identification by X-ray diffraction. The results of these analyses are given in table 3.

Geochemical Thermometers

Geochemical thermometers are being used to help describe and evaluate geothermal systems. Two geochemical thermometers, the silica geochemical thermometer (Fournier and Truesdell, 1970) and the Na-K-Ca (sodium-potassium-calcium) geochemical thermometer (Fournier and Truesdell, 1973) were used to estimate aquifer temperatures at depth in the Weiser area. In addition, a mixed-water geochemical thermometer, (Fournier and Truesdell, 1974) was used to estimate a maximum water temperature at depth and the percentage of cold water in the water sampled. This latter technique assumes that the water sampled is composed of a hot-water component from depth and a cold-water component from a shallower source.

The silica geochemical thermometer (curve A, Fournier and Truesdell, 1970) utilizes the silica concentration of the thermal water to obtain a temperature estimate. The temperature estimated is based on the assumption that the ascending water is cooled entirely by conduction, that the silica concentration of the water is in equilibrium with quartz, and that no dilution or precipitation of silica has occurred.

The Na-K-Ca geochemical thermometer utilizes the molar concentrations of Na, K, and Ca in the thermal water. The temperature estimates are based on the assumption that the concentrations of Na, K, and Ca are in chemical equilibrium with the thermal aquifer and that no dilution or enrichment occurs as the water ascends to the surface.

TABLE 3

MINERALOGY OF SELECTED HOT-SPRING DEPOSITS IN THE WEISER AREA, IDAHO

LOCATION	DESCRIPTION OF SAMPLE MATERIAL	SAMPLE MINERALOGY ^{1/}
11N-6W-10cca1	Active-spring deposit	Most of sample is water soluble. The insoluble residue consists of amorphous material, quartz, and feldspar. The water-soluble portion is, in part, tamarugite.
11N-6W-10cca1	Inactive-spring deposit	Sample consists of 15 to 20 percent plagioclase feldspar, 10 percent quartz, and possibly some augite. Clay minerals are present as well as zeolites.
11N-3W- 7bdb1S	Active-spring deposit	Sample contains 3 to 5 percent quartz, 5 percent plagioclase feldspar, 15 percent calcite, some clay minerals, and the remainder is amorphous material.
11N-3W- 7bdb1S	Active-spring deposit	Sample is primarily amorphous material, with a few percent each of quartz, plagioclase feldspar, and calcite.
11N-3W- 7bdb1S	Inactive-spring deposit	Sample contains 20 percent plagioclase feldspar, 3 to 5 percent quartz, some clay minerals, and the remainder is amorphous material.
11N-3W- 7bdb1S	Inactive-spring deposit	Sample is composed only of amorphous material.
10N-3W- 9ccc1S	Active-spring deposit	Sample contains 10 percent quartz, 5 percent calcite, 5 percent potassium feldspar and the remainder is primarily amorphous material.

^{1/} Analyses by U. S. Geological Survey, Denver, Colorado.

A thermal-water sample from a spring or well may, as indicated previously, be composed of hot water from depth that has mixed with a shallower cold water. The original temperature of the hot-water component and the percentage of cold water in the mixture can be estimated (Fournier and Truesdell, 1974) from the temperature of the water sampled, the silica concentration of the mixture, and the temperature and silica concentration of the nonthermal ground water in the area. Fournier and Truesdell suggest using the Na-K-Ca geochemical thermometer to indicate whether or not the sampled thermal water is of mixed origin. According to them, temperatures estimated using the Na-K-Ca geochemical thermometer that are within about 25°C of the temperature of the water at the surface usually indicate that mixing has not occurred, whereas estimated temperatures at depths that are not within 25°C of the temperature of the water at the surface strongly suggest a water of mixed origin.

Estimated temperatures were calculated using the mixed-water geochemical thermometer for samples from wells and springs where Na-K-Ca estimated temperatures exceeded the surface temperature by 25°C. The temperature and the percentage of cold water was computed using the following assumptions (Fournier and Truesdell, model 1, 1974): (1) water and newly formed steam rise together, (2) the silica concentrations are in equilibrium with quartz, and (3) the temperature and the silica concentration of water sampled from nonthermal springs are representative of the nonthermal ground water in each area.

Estimated aquifer temperatures calculated using the three geochemical thermometers described are given in table 4 and shown on figure 8.

Chemical Ratios

The ratios of certain chemical constituents (White, 1970) can be used to help describe and evaluate the origin of thermal water. The atomic and molar ratios of selected chemical constituents from sampled wells and springs in the Crane Creek and Weiser Hot Springs subareas are given in table 4. Included in this table are the following ratios that have been used to identify similar waters within a geothermal area: (1) $\text{Cl}/(\text{HCO}_3 + \text{CO}_3)$ (chloride/bicarbonate plus carbonate), Fournier and Truesdell (1970); Cl/B (chloride/boron), Ellis (1970); and Cl/F (chloride/fluoride), Mahon, (1970). These selected ratios are also shown in figure 9.

Crane Creek Subarea

The chemistry of the sampled thermal water in the Crane Creek subarea indicates that the water is of a sodium chloride sulfate type. The water is slightly alkaline with pH values ranging from 7.1 to 8.0. Dissolved-solids concentrations range from 1,070 to 1,140 mg/l (milligrams per litre). Sampled nonthermal ground water is of a calcium or sodium bicarbonate type and contains less than 300 mg/l dissolved solids. Chloride concentrations (table 2) in the thermal water in this subarea range from 200 to 310 mg/l. Chloride concentrations in this range indicate that a hot-water system with temperatures above 150°C may exist at depth (White, 1973, p. 8). Ground-water temperatures measured at the surface range from 13.5° to 92.0°C (fig. 8) with the highest temperature at spring 11N-3W-7bdb1S.

TABLE 4

ESTIMATED AQUIFER TEMPERATURES AND CHEMICAL RATIOS OF SELECTED CONSTITUENTS IN THE WEISER AREA, IDAHO

Well or Spring Identification Number	Discharge (cubic feet per second)	Water Temperature at Surface (°C)	Aquifer Temperatures from Geochemical Thermometers (°C)				ATOMIC RATIOS										MOLAR RATIOS			
			a) Silica	b) Mixed Water Method		c) Potassium-Calcium	Sodium-Potassium Na/K	Magnesium-Calcium Mg/Ca	Sodium-Calcium Na/Ca	Chloride-Fluoride Cl/F	Chloride-Boron Cl/B	Chloride-Lithium Cl/Li	Sodium-Lithium Na/Li	Sodium-Boron Na/B	$\sqrt{\text{Calcium Sodium}} \sqrt{\text{Ca/Na}}$	Calcium-Bicarbonate Ca/HCO ₃	Chloride-Bicarbonate plus Carbonate Cl/HCO ₃ + CO ₃	Chloride-Bicarbonate Cl/HCO ₃	Chloride-Sulfate Cl/SO ₄	
				Temp. Hot Water	Percent Cold Water															
12N-7W- 24add1S	0.01	15.0	-	-	-	-	5.44	0.290	2.09	4.42	-	16.1	181	-	0.677	0.236	0.044	0.044	0.406	
12N-4W- 34abb1S	.01	13.5	-	-	-	-	5.67	.604	.755	2.68	-	34.3	196	-	1.53	.273	.036	.036	.729	
11N-6W- 3dbb1	.01	23.5	94	d*	d*	45	340	-	47.5	7.90	4.27	548	3,620	28.2	.063	.100	.719	.719	.421	
3dcb1	.01	25.0	123	d*	d*	68	184	.041	56.7	49.1	6.99	538	1,960	25.5	.056	.406	1.83	6.31	.993	
9dab1	-	14.5	63	d*	d*	80	221	.097	133	6.00	12.2	219	785	43.7	.036	.012	.450	.450	7.22	
10acb1S	.01	21.5	81	d*	d*	42	60.7	.247	7.26	7.59	6.33	-	-	28.7	.252	.415	.665	.665	.869	
10cca1	.01	70.5	157	242	76	142	47.6	-	84.2	9.09	7.77	274	1,060	29.9	.044	.126	1.31	2.75	1.01	
10cca2	-	77.0	153	214	70	145	44.9	.061	90.4	7.14	7.21	204	845	29.9	.043	.125	1.20	2.71	.939	
10cca3	-	76.0	157	228	72	141	49.6	-	93.9	10.3	8.14	219	845	31.4	.042	.124	1.38	3.01	1.01	
15bcb1S	.04	14.5	127	d*	d*	83	33.5	.560	9.07	13.4	9.81	176	785	43.7	.140	.223	.453	.453	.677	
17bdd1	.01	18.5	74	d*	d*	19	258	-	8.35	20.3	7.70	207	549	20.4	.174	9.64	3.75	30.4	1.10	
18ccc1S	.01	17.0	65	d*	d*	3	2,120	.061	22.9	7.42	2.68	50.3	539	28.7	.063	1.61	3.44	3.44	.191	
25cac1	-	13.0	-	-	-	-	22.0	.724	1.27	6.16	11.7	90.0	1,450	188	.615	.256	.020	.020	.304	
11N-5W- 20bdd1	-	21.0	106	200	97	61	5.18	.282	1.18	7.29	41.5	26.6	127	198	.963	.347	.086	.086	.737	
11N-4W- 12ocb1	-	15.5	-	-	-	-	17.4	.292	11.9	91.1	8.79	25.6	207	71.0	.147	.085	.126	.126	3.54	
12cdc1	-	17.0	-	-	-	-	2.63	.676	1.13	5.63	5.83	41.1	392	55.6	1.25	.256	.030	.030	.677	
11N-3W- 7bdb1S	.01	92.0	173	235	67	163	26.5	.028	16.8	33.5	6.10	63.1	136	13.2	.070	.220	1.71	1.71	2.17	
7bdb2S	.01	57.0	177	d*	d*	166	25.1	.034	16.8	33.5	6.10	62.1	134	13.2	.070	.219	1.70	1.70	2.17	
7cbb1S	.10	77.0	173	270	76	163	27.4	.019	19.4	28.2	5.55	59.3	133	12.4	.064	.201	1.75	1.75	2.26	
10N-3W- 9ccc1S	.01	74.0	153	212	70	172	24.7	.016	27.9	35.3	12.1	108	172	19.3	.051	.285	4.99	4.99	3.11	

a) Using curve A (equilibrium with quartz) Fournier and Truesdell, 1970.

b) Model 1, Fournier and Truesdell, 1974.

c) Fournier and Truesdell, 1973.

d) *No temperature estimated by mixed-water method (model 1, Fournier and Truesdell, 1974).

Aquifer temperatures estimated using the silica geochemical thermometer indicate that temperatures at depth range from 153° to 177°C. Aquifer temperatures estimated using the Na-K-Ca geochemical thermometer suggest that temperatures at depth range from 163° to 172°C, which is in good agreement with temperatures estimated using the silica thermometer. Mixed-water temperatures were calculated for samples from three springs in the Crane Creek subarea. The temperatures estimated using this method range from 212° to 270°C, with cold water comprising 67 to 76 percent of the water at the surface.

Boron concentrations (table 2) in samples of hot-spring water ranged from 7,800 to 11,000 ug/l (micrograms per litre). The water from the nonthermal spring, which was sampled for background data in this subarea (12N-4W-34abb1S) did not contain boron. Water from two shallow wells (11N-4W-12ccb1 and 11N-4W-12cdc1, fig. 4) contained boron concentrations of 590 and 110 ug/l, respectively, which may indicate that there is some thermal water leaking into the shallow ground-water system in this subarea.

Lithium concentrations for all waters sampled ranged from 10 to 660 ug/l. Concentrations in the thermal waters were markedly higher, 560 to 660 ug/l, than in nonthermal waters, 10-20 ug/l.

Mercury concentrations in the thermal and nonthermal waters sampled ranged from 0 to 0.3 ug/l and showed no appreciable differences between the two waters. Similarly, no general differences were found in arsenic concentrations in the thermal and nonthermal waters sampled, although spring 10N-3W-9ccc1S contained 510 ug/l and well 11N-4W-12ccb1 contained 170 ug/l of arsenic. The significance of the anomalous lithium and arsenic concentrations is not now understood.

The respective $Cl(HCO_3 + CO_3)$, Cl/B, and Cl/F ratios (fig. 9) for sampled hot-spring water along Crane Creek are very similar and indicate that the thermal water is from the same aquifer. The ratios of these constituents in water from spring 10N-3W-9cc1S, located approximately 7 miles south along Cove Creek, were higher. These higher ratios are due chiefly to the higher chloride concentrations of the water at this spring. However, the similarity of the water from this spring and the springs located at the Crane Creek site indicate that the water could conceivably be from the same thermal aquifer.

The presence of a large number of mounds composed of sinter (amorphous siliceous material) distinguish the hot springs occurring along Crane Creek from springs found elsewhere in Idaho. Some of the mounds from which water no longer issues appear to be quite old. Others appear to have been overlapped by younger deposits from which some hot water still issues (springs 11N-3W-7bdb1S and 11N-3W-7bdb2S). At spring 11N-3W-7cbb1S, from which the largest volume of water issues, little if any sinter has as yet been deposited, and a mound has not been formed. The migration of the hot-spring vents apparent here and the large mounds of sinter that have been formed are a consequence of the silica-rich thermal waters. Evidently, as the thermal waters reach the land surface and cool, silica is precipitated out and thus gradually builds a mound of sinter around the spring vent. With time, as the mound enlarges, silica is precipitated in the vent and spring channel, and the vent is thereby gradually choked off to the extent that it can no longer transmit water. A new vent is then formed where the water has succeeded in finding a new permeable channel to the surface.

Samples of hot-spring deposits along Crane Creek at both active- and inactive-spring sites are primarily sinter with minor amounts of quartz, feldspar, calcite, and clay minerals. The feldspar and clay minerals probably represent country rock that was incorporated into the spring deposits during deposition. The presence of sinter deposits (White, 1970) at the spring vents in the Crane Creek subarea indicates that the water depositing this material was in excess of 180°C at depth.

Weiser Hot Springs Subarea

The thermal water in the Weiser Hot Springs subarea is mostly a sodium sulfate type water and is alkaline with pH values ranging from 7.2 to 9.3. Dissolved-solids concentrations range from 225 to 852 mg/l. The nonthermal ground water (as represented by water from spring 12N-7W-24add1S and well 11N-6W-25cac1) is of a calcium bicarbonate type having dissolved-solids concentrations of 192 and 466 mg/l, respectively.

The chloride concentration for thermal waters sampled in this area is generally about 50 mg/l. Chloride concentrations of 50 mg/l or higher in thermal waters generally indicate a hot-water system at depth (White, 1970). Ground-water temperatures measured at the surface (fig. 8) range from 13.0°C at well 11N-6W-25cac1 to 77.0°C at well 11N-6W-10cca2.

Boron concentrations (table 2) in the water from all wells and springs sampled in the Weiser Hot Springs subarea range from 0 to 4,100 ug/l. Regardless of surface temperatures, all sampled wells and springs near the Weiser Hot Springs, with the exception of spring 12N-7W-24add1S (sampled for background data) approximately 7 miles northwest of Weiser Hot Springs, and two wells (11N-6W-25cac1 and 11N-5W-20bdd1) approximately 5 and 3 miles southeast of Weiser Hot Springs, respectively, have high boron concentrations. The noticeably high boron concentrations in the immediate vicinity of the Weiser Hot Springs may indicate leakage of thermal water into the shallow ground-water system.

Lithium, mercury, and arsenic concentrations for most sampled waters in the Weiser Hot Springs subarea are less than 100 ug/l. The exception is spring 11N-6W-18ccc1S, where the lithium concentration was 140 ug/l.

Aquifer temperatures estimated using the silica geochemical thermometer range from 63° to 157°C. Aquifer temperatures estimated using the Na-K-Ca geochemical thermometer range from 3° to 145°C. This large range in estimated temperatures may be due to a mixing of thermal and nonthermal waters, which can affect the chemical composition of the water. Temperatures estimated using samples from the wells drilled at the Weiser Hot Springs show very good agreement and range from 153° to 157°C for the silica method and 141° to 145°C for the Na-K-Ca method.

Mixed-water temperatures were estimated using samples from the four wells in the Weiser Hot Springs subarea. Maximum estimated temperatures ranged from 200° to 242°C with the cold-water component making up 70 to 97 percent of the water sampled.

The Cl(HCO₃ + CO₃), Cl/B, and Cl/F ratios (fig. 9) for water from the sampled wells and springs in the Weiser Hot Springs subarea have a large range in values; however, the

general similarity in ratios, particularly the Cl/B ratio, indicates that the waters sampled are probably from the same aquifer. The differences in calculated ratios are probably due to mixing of the thermal water with nonthermal water.

Samples of hot-spring deposits (table 3) collected at the Weiser Hot Springs from both active- and inactive-spring vents consist of sinter, quartz, feldspar, water-soluble residue, calcite, and minor amounts of clay minerals. The quartz, feldspar, and clay minerals probably represent country rock that was incorporated into the spring deposit at the time of deposition. The water-soluble residue is probably evaporites deposited when hot water evaporated at the surface.

Development of the thermal water by the drilling of four wells has virtually eliminated all natural discharge from these springs.

Some Considerations Regarding the Occurrence and Evaluation of Thermal Water in the Weiser Area

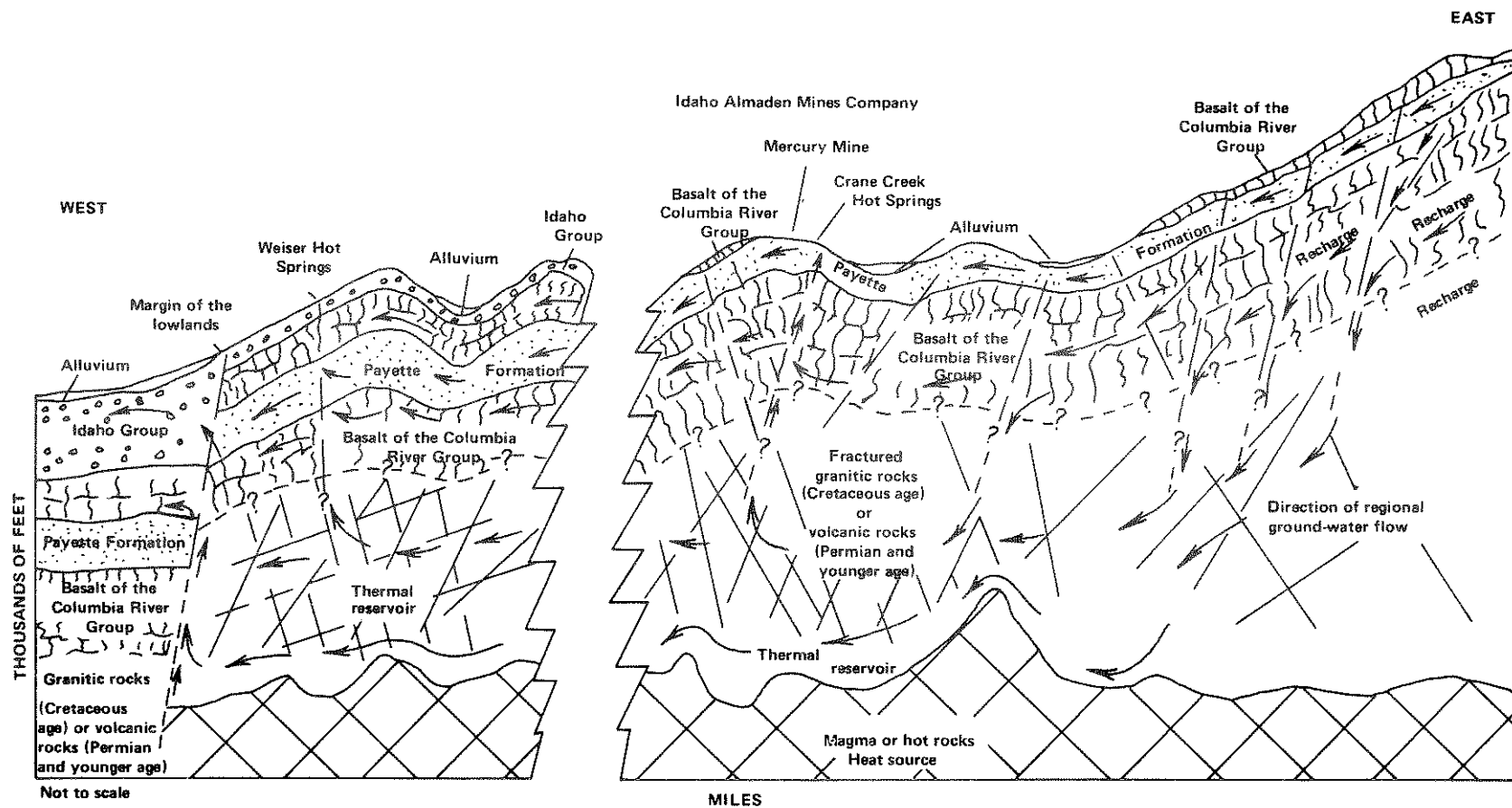
Four important factors to consider in evaluating the geothermal potential of an area are:

- (1) A Source of heat;
- (2) A reservoir in which to store heated water;
- (3) A flow regime to circulate heated water to points of discharge; and
- (4) A source of recharge to replace discharged water.

The source of the heat that warms the water issuing from the thermal springs in the Weiser area is not known and can only be speculated on. Washburne (1909) reported that the numerous hot springs of the region were generally thought to be associated with underlying hot lavas. He also reported that certain of the hot springs in eastern Oregon, in particular those nearby at Vale, Oregon, may be yielding water from a great depth or water that has escaped from ascending magmas rather than meteoric water that has been heated by contact with hot lavas. Kirkham (1935) mentioned the association of hot water with volcanic plugs, and he reported that the highest temperature water was found in those areas closest to the intrusive rocks. Kirkham (1935) concluded that the occurrence of hot water in areas where no intrusive rocks were at the surface suggests that the heat source is probably a sill rather than a plug.

Existing geologic and geophysical data are too sparse to indicate whether or not a shallow heat source(s) underlies the Crane Creek and Weiser Hot Springs subareas. Geologic factors that may indicate the presence of a relatively shallow heat source(s) in the area are: (1) the nearby downfaulted block of the Snake River Plain that may have displaced underlying magma laterally and thereby caused an upward movement of magma in the Weiser area; (2) the extensive structural deformation that occurred in the area during Miocene, Pliocene, and early Pleistocene time; (3) the opalization and mercury enrichment of rocks by solutions that may have emanated from shallow magmatic intrusions along fault systems, possibly as recently as early Pleistocene time; and (4) the reported presence of a rhyolite(?) dike (not shown on the geologic map nor previously discussed, which may be indicative of a shallow intrusion) in the canyon of Crane Creek just upstream from the hot

FIGURE 10. Schematic geohydrologic section for the Weiser area, Idaho.



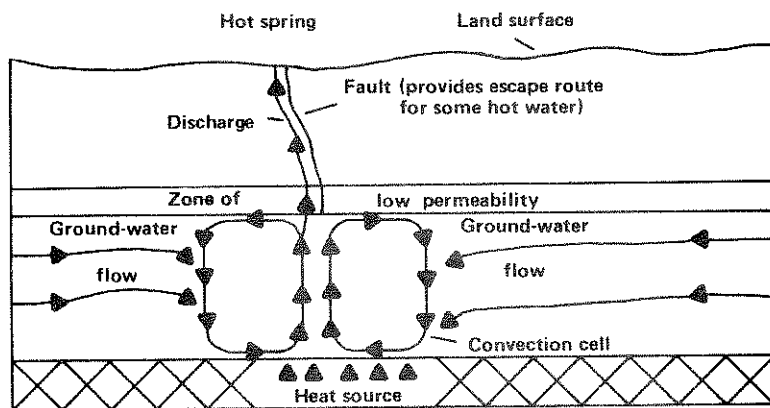
springs. Although the geophysical data collected do not indicate the presence of any shallow intrusive rock, the data are sparse and for this reason are not definitive. However, the few AMT soundings made did show that a shallow resistivity anomaly is present in the area. This anomaly could be indicative of an underlying shallow heat source. Also, an indication by Pakiser (1963) that a thinning of the earth's crust does occur in this area enhances the possibility that an intrusive magmatic body exists at shallow depths.

For an area to have geothermal potential, a reservoir capable of storing, transmitting, and yielding large quantities of water must be available. The lack of subsurface data greatly inhibits description of the hot-water reservoir in the Weiser area. As indicated previously, the reservoir could occur in (a) basalt or sedimentary rocks of the Columbia River Group, (b) fractured granite of the Idaho batholith of Cretaceous age, or (c) undifferentiated volcanic and consolidated sedimentary rocks of Permian and younger age. Interflow zones, sedimentary rocks, and fractures in rocks of the Columbia River Group could constitute a significant reservoir capable of yielding large quantities of hot water or steam, particularly if alteration of the rocks has occurred. Similarly, fractures in zones of faulting could provide a large reservoir in the underlying Cretaceous granite and the Permian and younger volcanic and sedimentary rocks, if these rocks are present.

Recharge to the reservoir supplying the hot water to springs and wells in the Weiser area is probably derived from precipitation on nearby mountains that moves downward through cracks and fractures in the surficial rocks to heated rocks at depth (fig. 10). Most of the precipitation on the mountains occurs in winter as snow. Although the Weiser Basin is generally regarded as being hot and dry, relative to many other areas in Idaho, snowfall on the mountains is significant. At the Boulder Creek and Placer Creek snow courses (60 and 40 miles north of Weiser, respectively), snow depths were 96 inches (water content 33.6 inches) on February 26, 1974, and 74 inches (water content 23.5 inches) on March 2, 1974, respectively (U.S. Soil Conservation Service, 1974).

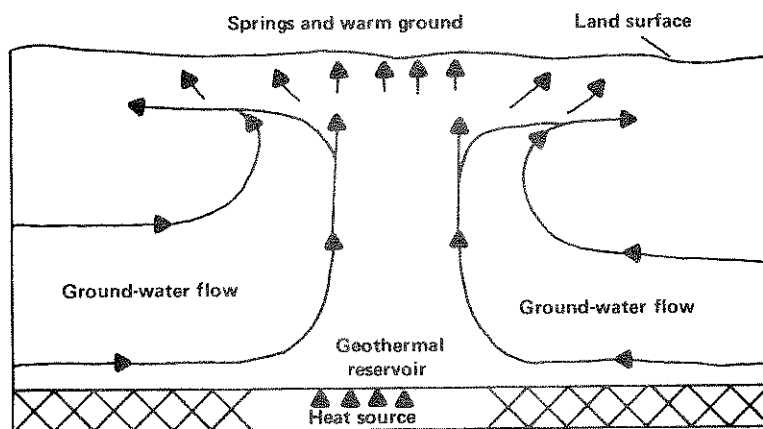
It is generally considered that for a geothermal reservoir to successfully function as a significant source of hot water or steam, it must be capped by material of lesser permeability and a convection cell formed. In such a cell, the circulating water can attain temperatures high enough to make it useful for power generation. An idealized schematic depiction of a localized geothermal-convection cell formed in a confined reservoir as a result of the upward flow of heat from a local heat source is shown in figure 11. The temperature attained in a cell of this type is a function of (1) the amount of heat available to the cell, (2) the amount of water leaving the cell either by upward leakage or by lateral flow, or (3) the upward leakage of heat by conduction.

At the Almaden mercury mine, a near-surface cap rock, (partially eroded away) prevented the upward movement and dissemination of mercury vapors to the atmosphere, thus causing them to precipitate in the rock. This indicates that the mercury-bearing solutions (vapors) were able to move relatively freely upward from the source of the mercury (a shallow intrusive body?) to the cap rock and that, consequently, no relatively impermeable rock layer exists between the shallow cap rock and the postulated deep intrusive source. For this reason, it is unlikely that a capped geothermal reservoir underlies the area around the mercury mine. Similarly, other nearby areas wherein mercury-bearing and opalized rocks are found may not be underlain by a capped reservoir in which hot water can be stored. Additional evidence that a capped reservoir may not exist at depth is



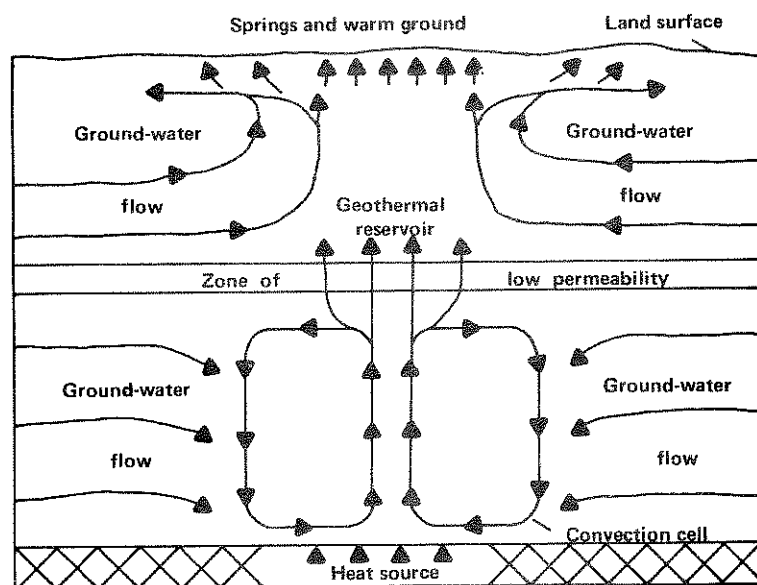
Not to scale

FIGURE 11. Schematic showing a geothermal convection cell.



Not to scale

FIGURE 12. Schematic showing warm water rising directly to the land surface from a geothermal reservoir.



Not to scale

FIGURE 13. Schematic showing a combination of two geothermal reservoirs.

provided by the fact that the hot waters of the area have low dissolved-solids concentrations (less than 1,140 mg/l). These low concentrations of dissolved solids indicate that the water has moved from a recharge area to the discharge area relatively quickly. Had the water been circulating and stored for a long time in a geothermal reservoir of the type illustrated in figure 11, more mineral solution and, therefore, higher dissolved solids concentrations would be expected. Nevertheless, it is possible that a reservoir of the type illustrated in figure 11 does occur in the Weiser area and that the water in the reservoir leaks upward at small rates through fractures or faults in the capping rocks.

It is quite likely that a hot-water reservoir of the type sketched in figure 12 underlies some part of the Weiser area. In this type of reservoir, the recharge water is heated at depth, rises relatively freely, and the heat in the water is dissipated at shallow depths. Because the water does not circulate in a convection cell, it does not attain a very high temperature. Often, however, temperature eminently suitable for agricultural, recreational, and space-heating purposes is attained.

It is also possible that a combination of the two types of geothermal reservoirs illustrated by figures 11 and 12 does occur, although such has not yet been found elsewhere. As illustrated in figure 13, a reservoir containing a convection cell could underlie the simpler type of free-flowing reservoir. Hot water or steam moving upward through faults or other more permeable zones from the lower reservoir could be the heat source for the upper reservoir.

As indicated by the above discussion, hot water can occur under quite simple to extremely complex conditions. Certainly, the manner in which it occurs in the Weiser area is unknown. For this reason, the full potential for development of the thermal water in this area cannot now be assessed. Definition of the reservoir supplying the hot water issuing from springs and wells and assessment of the potential of the Weiser area as a geothermal prospect can be accomplished by the use of test drilling and other exploratory techniques as described and discussed below:

1. **Preparation of a detailed geologic map of the area.** This map would be useful in not only providing knowledge of the structure, lithology, and stratigraphy of the surficial rocks, but would also serve as a valuable guide to selecting areas where geophysical surveys should be made, and in locating test-drilling sites.
2. **Geophysical surveys using gravity, AMT, and deep-resistivity techniques.** The gravity surveys would provide knowledge of deep structural features and depths to bedrock. The AMT surveys would be used to map such conductive (hot water) anomalies as may exist in the subsurface. The deep-resistivity survey would be used to help define subsurface rock units and structures, and to help locate such intrusive bodies as might be present in the subsurface.
3. **Drilling of test holes.** Utilizing the data provided by items 1 and 2, test wells could be sited to provide a maximum of information. Depth of the test holes needed could also be estimated using the information gained from items 1 and 2. Information to be collected should include (1) the lithology, thickness, and depth of the rock units overlying the basement complex; (2) water-quality data for the formations penetrated; (3) water-level and water-yield data; and (4) water and rock temperatures at selected depths.

SUMMARY

The Weiser area comprises about 200 square miles in southwestern Washington County and includes two subareas having thermal water: the Crane Creek subarea, which is about 12 miles east of Weiser, and the Weiser Hot Springs subarea, which is about 5 miles northwest of Weiser.

Although the surficial geology of the Crane Creek and Weiser Hot Springs geothermal subareas is somewhat different, the general stratigraphy is similar. Volcanic and sedimentary rocks of Permian and younger age, granite of Cretaceous age, or the older basalts of the Columbia River Group of Miocene and Pliocene age may underlie the Weiser area. However, the scant data available indicate that the reservoir rock is most likely composed of the older basalts of the Columbia River Group. Miocene and Pliocene(?) sedimentary rocks termed the Payette Formation overlie older basalts and are, in turn, overlain by a younger sequence of basalts of the Columbia River Group. For the most part, sedimentary rocks of the Idaho Group of Pliocene and Pleistocene age overlie the younger basalts. Alluvium and colluvium of Pleistocene and Holocene age cover much of the older rock units, particularly in the lowlands and valleys.

Gravity surveys indicate that the Weiser area is at the northwest end of a large regional gravity high that is associated with the western Snake River Plain. The Crane Creek subarea is characterized by an extensive gravity low. A low-amplitude gravity high indicates that a dense, anomalous, near-surface mass may underlie the Weiser Hot Springs subarea. Magnetic lows are found in both the Crane Creek and Weiser Hot Springs subareas. Preliminary audio-magnetotelluric soundings suggest that an anomalous conductive zone is present at shallow depths in both subareas.

A ground-temperature survey made in the Weiser Hot Springs subarea apparently outlines an area of high heat flow centered at or near the Weiser Hot Springs, and it also correlates very well with high boron concentrations measured in water samples collected in the area of the survey.

Most of the thermal waters sampled in the Weiser area are of a sodium chloride sulfate or sodium sulfate type. Dissolved-solids concentrations ranged from 1,070 to 1,140 mg/l for thermal water in the Crane Creek subarea and from 225 to 852 mg/l in the Weiser Hot Springs subarea. Thermal water sampled in the Crane Creek subarea had noticeably higher concentrations of chloride and boron than did thermal water sampled in the Weiser Hot Springs subarea.

Measured ground-water temperatures ranged from 13.0° to 92.0°C, and were highest at a spring in the Crane Creek subarea. Estimated aquifer temperatures, using the silica and the sodium-potassium-calcium geochemical thermometers, ranged from 153° to 177°C in the Crane Creek subarea and from 3° to 157°C in the Weiser Hot Springs subarea. Estimated aquifer temperatures for samples from wells at the Weiser Hot Springs ranged from 141° to 157°C. In the Crane Creek and Weiser Hot Springs subareas, respectively, estimated maximum temperatures at depth, using the mixed-water method, ranged from 212° to 270°C and from 200° to 242°C with percentages of cold water ranging from 67 to 76 percent and from 70 to 97 percent.

Analyses of hot-spring deposits from active- and inactive-spring vents indicated that, although the mineral constituents in samples from both subareas are similar, the deposits in the Crane Creek subarea contain much greater amounts of sinter than those from the Weiser Hot Springs subarea. This indicates that the water depositing this material was at temperatures in excess of 180°C at depth.

The source of the heat for the thermal water in the Weiser area is believed to be a cooling young intrusive implanted at shallow depth in late Miocene or early Pleistocene time, or above-normal heat flow caused by the high temperatures at relatively shallow depth resulting from a general thinning of the earth's upper crust in this area.

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Qal	Holocene and Pleistocene	QUATERNARY
QTiu	Pleistocene and Pliocene	TERTIARY
Tcr	Pliocene and Miocene	TERTIARY
PT		PRE-TERTIARY

DESCRIPTION OF MAP UNITS

- Qal SURFICIAL DEPOSITS--Alluvium and colluvium, includes clay, silt, sand, gravel, and some landslide debris.
- QTiu IDAHO GROUP, UNDIFFERENTIATED--Poorly to well sorted fluvial and lacustrine deposits of clay, silt, sand, and gravel, compacted to poorly consolidated. Contains some beds of ash and intercalated basaltic lava flows.
- Tcr BASALT OF THE COLUMBIA RIVER GROUP--Flood-type basalt, light to dark gray, dense, crude columnar jointing at places, folded and faulted, and may include some andesitic and rhyolitic rock types. Payette Formation is sandwiched between units of this basalt at places.
- TP PAYETTE FORMATION--Compacted beds of clay, silt, sand, and volcanic ash intercalated in basalt of the Columbia River Group.
- PT PRE-TERTIARY ROCKS, UNDIFFERENTIATED--Includes Seven Devils Volcanics of Permian and Triassic age and related rocks--including sedimentary rocks and some granitic rocks of the Idaho batholith of Cretaceous age.

ROCKS AFFECTED BY OPALIZATION (Ross, 1956)

SYMBOLS

- ANTICLINE, SHAH (1966)
- SYNCLINE, SHAH (1966)
- ANTICLINE, KIRKHAM (1931b)
- SYNCLINE, KIRKHAM (1931b)
- FAULT--Bar and ball on downthrown side
- INFERRED OR CONCEALED FAULT
- CONTACT

- 12cdcl WELL LOCATION AND NUMBER
- 9ccclS SPRING LOCATION AND NUMBER

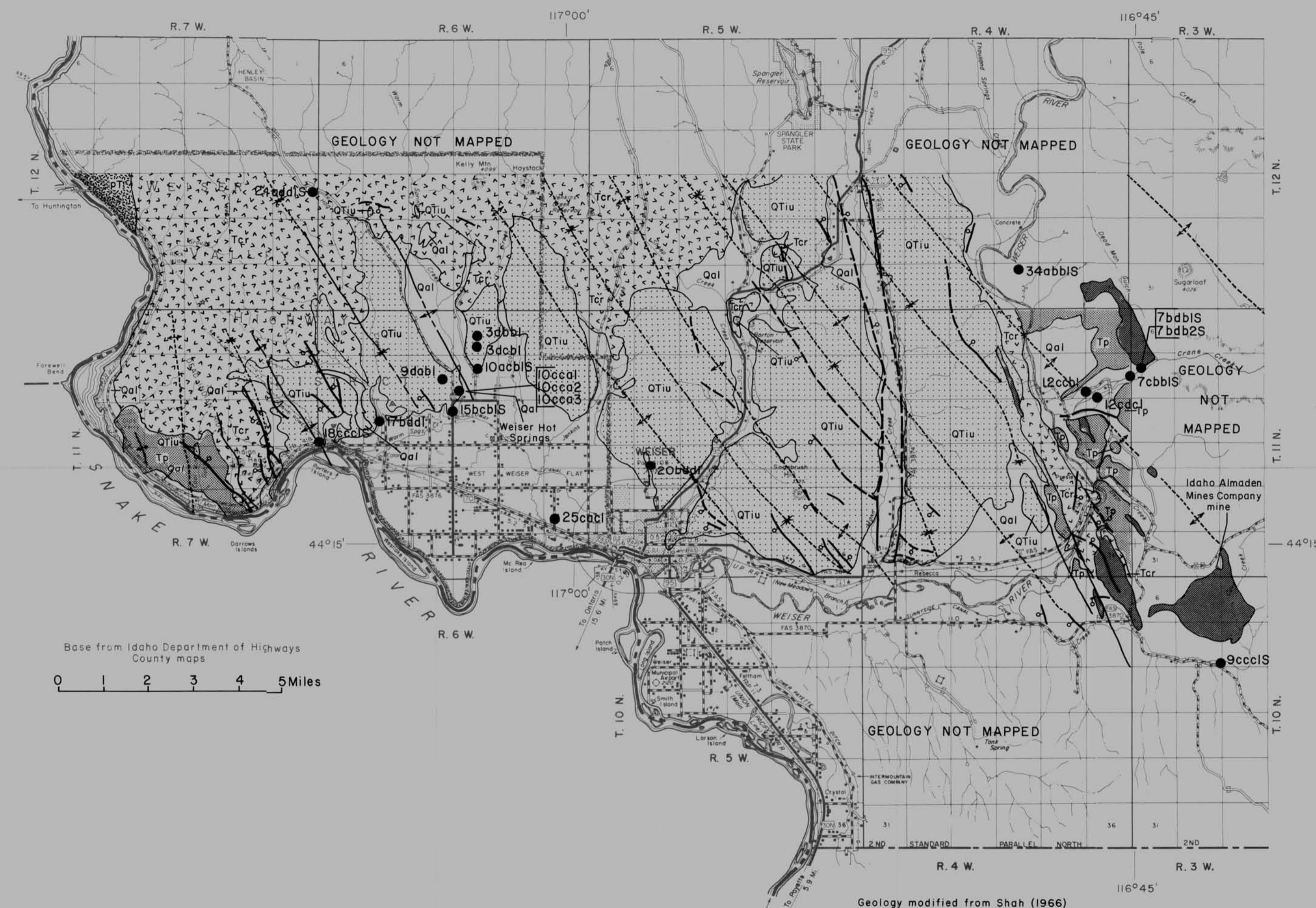


FIGURE 4.--Generalized geology and location of sampled wells and springs in the Weiser area, Idaho.

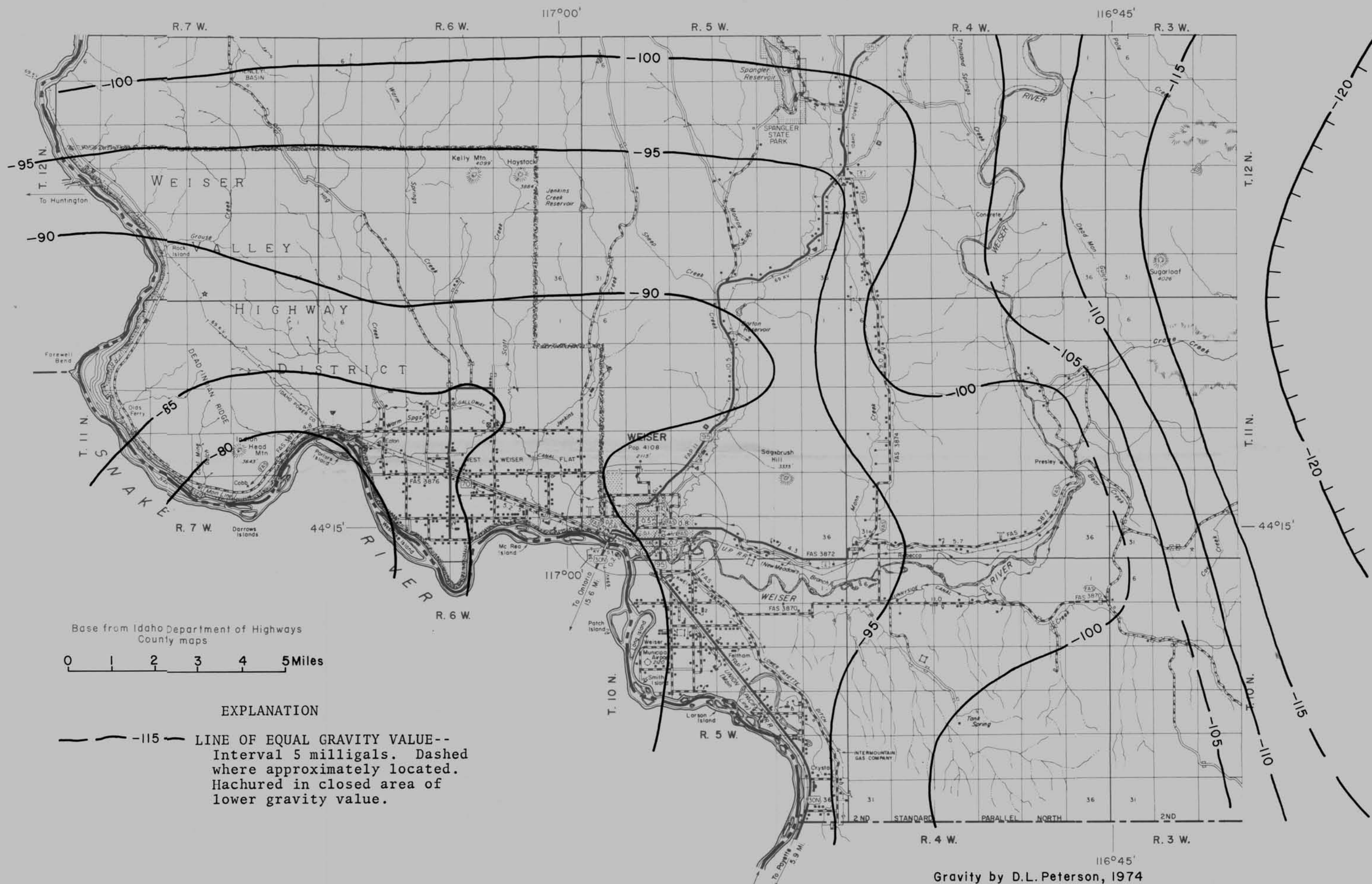


FIGURE 5.--Bouguer gravity map of the Weiser area, Idaho.

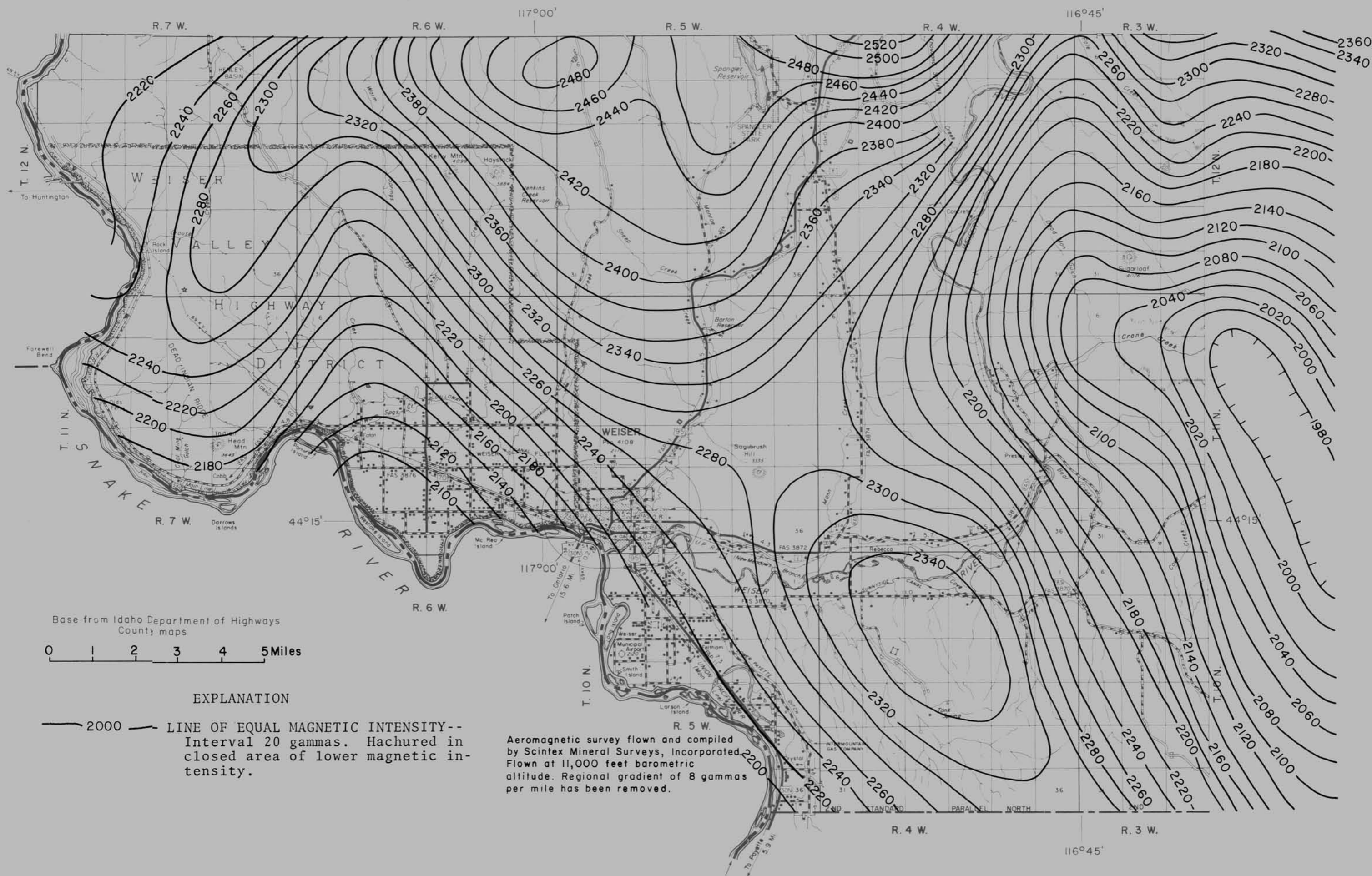
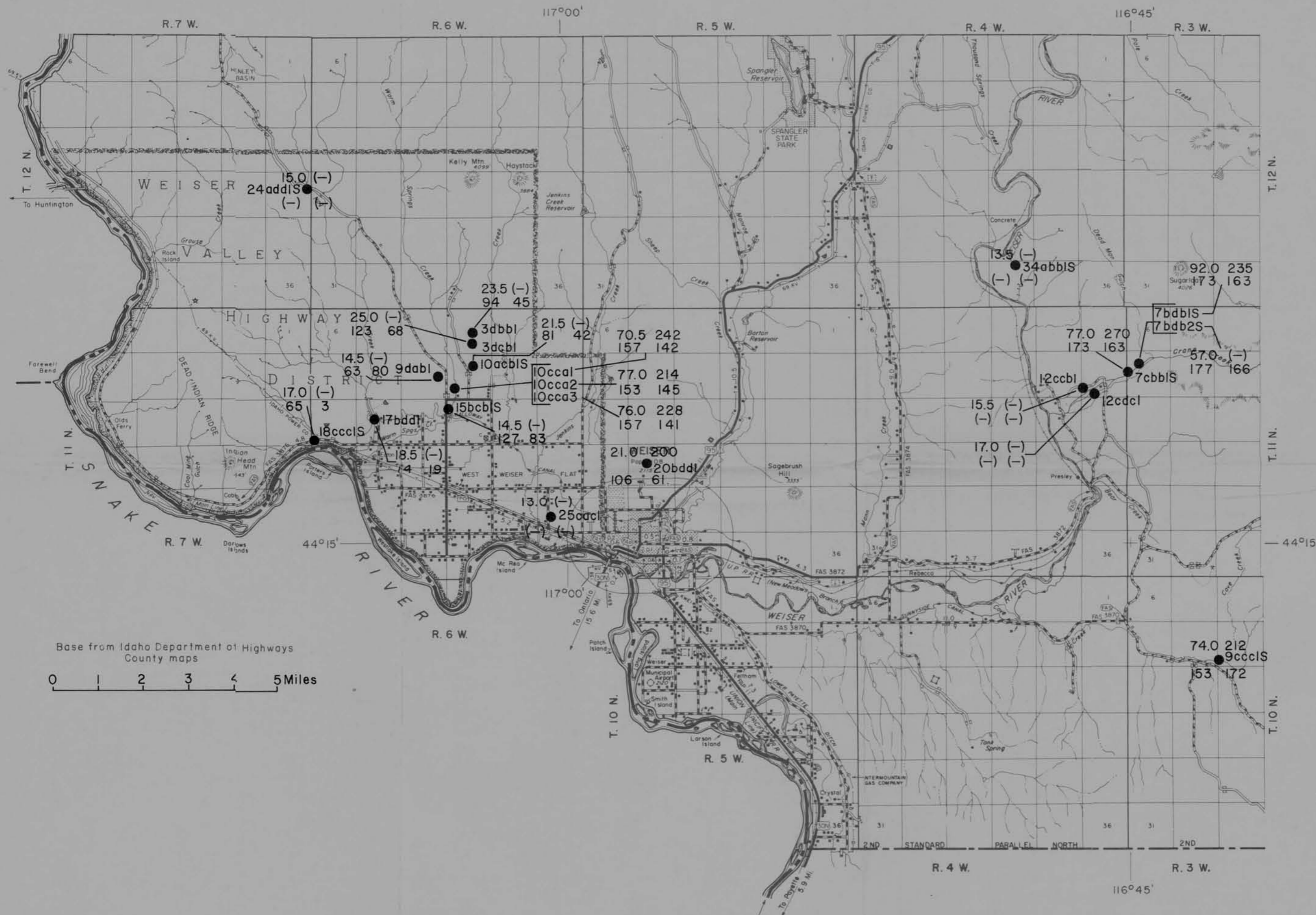


FIGURE 6.--Aeromagnetic map of the Weiser area, Idaho.

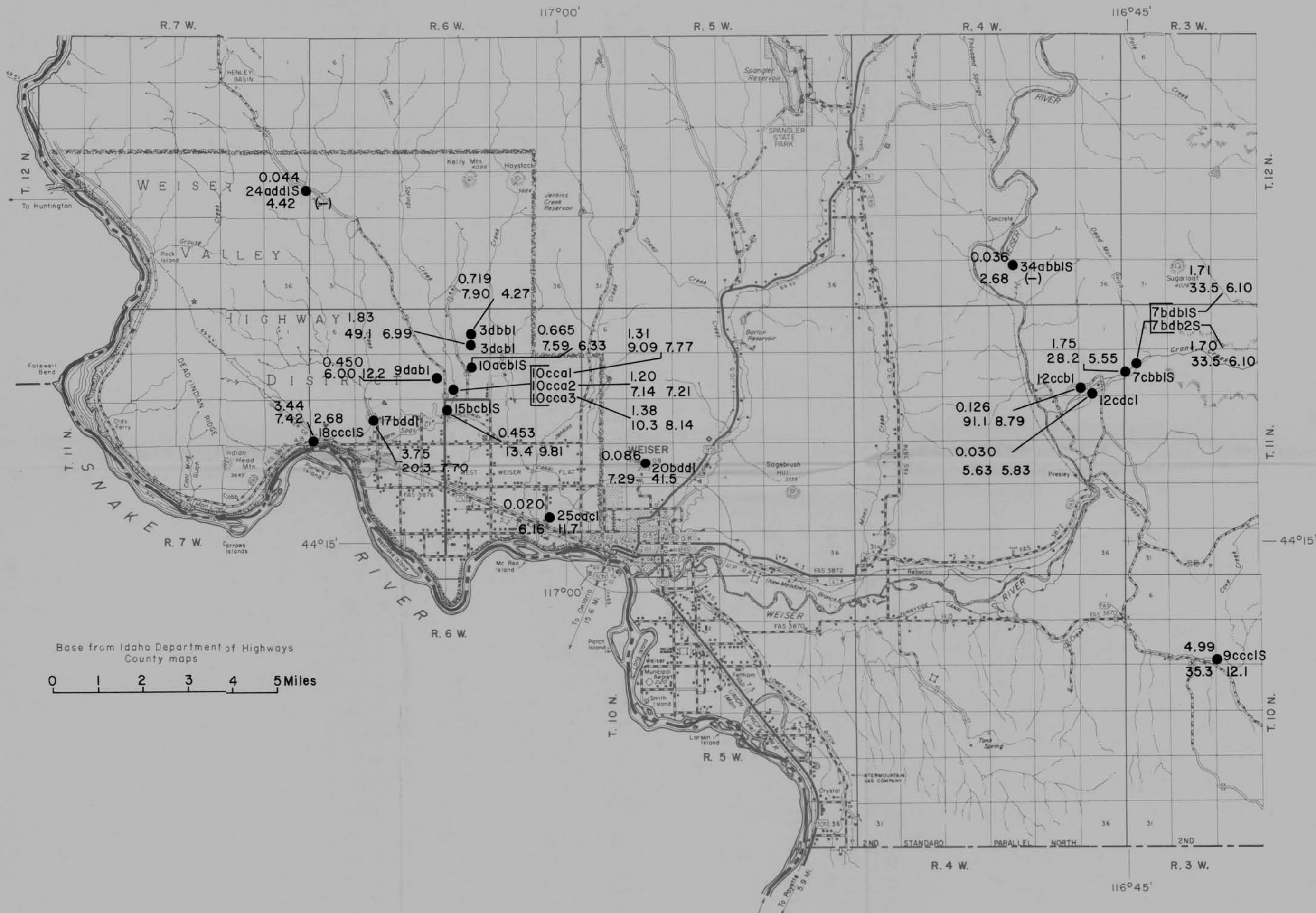


EXPLANATION

- | | | |
|------|-----|---|
| (1) | (4) | TEMPERATURES, IN DEGREES CELSIUS-- |
| 92.0 | 235 | (1) Measured water temperatures at the surface. (2-4) Estimated aquifer temperatures: 2, silica geochemical thermometer, curve A, Fournier and Truesdell (1970); 3, sodium-potassium-calcium geochemical thermometer, Fournier and Truesdell (1973); 4, Mixed-water geochemical thermometer (temperature of the hot-water component), Model 1, Fournier and Truesdell (1974). Dash in parentheses indicates no temperature estimated or obtained. |
| 173 | 163 | |
| (2) | (3) | |

- 12cdl SAMPLED WELL AND NUMBER
- 9ccclS SAMPLED SPRING AND NUMBER

FIGURE 8.--Estimated aquifer temperatures and water temperatures at the surface for sampled wells and springs in the Weiser area, Idaho.



(Cl/HCO₃+CO₃)

1.71

33.5 6.1
(Cl/F) (Cl/B)

EXPLANATION

CHEMICAL RATIOS--Cl, chloride;
HCO₃, bicarbonate; CO₃, car-
bonate; F, fluoride; B, boron

● 12cdcl SAMPLED WELL AND NUMBER

● 9ccclS SAMPLED SPRING AND NUMBER

FIGURE 9.--Ratios of selected chemical constituents for sampled wells and springs
in the Weiser area, Idaho.